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Perry et al.

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(45) **Date of Patent: Feb. 23, 2016**

(54) **CIRCUIT DESIGN SYNTHESIS TOOL WITH EXPORT TO A COMPUTER-AIDED DESIGN FORMAT**

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(73) Assignee: **TEXAS INSTRUMENTS INCORPORATED**, Dallas, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: **Jul. 9, 2014**

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Related U.S. Application Data

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G06F 17/50 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/5072*** (2013.01); ***G06F 17/5081*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 2217/78; G06F 17/5072; G06F 17/5081; H05K 3/0005
See application file for complete search history.

(56) **References Cited**

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2006/0053341	A1 *	3/2006	Haarberg et al.	714/34

* cited by examiner

Primary Examiner — Nha Nguyen
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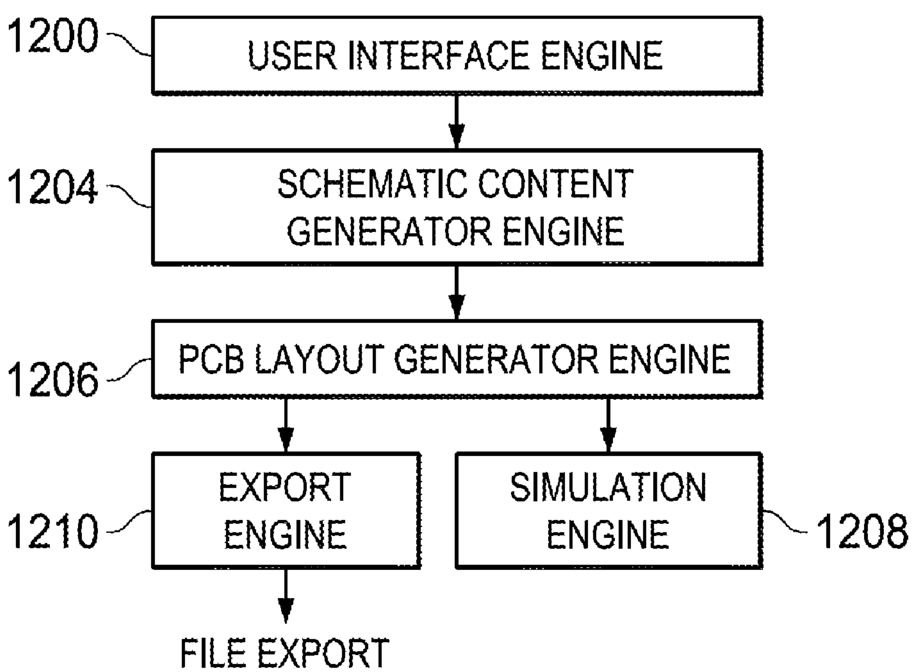
(57) **ABSTRACT**

A method (and related apparatus) includes receiving user input and generating at least one of schematic content for a circuit based on the received user input and a printed circuit board (PCB) layout based on the circuit. The method further includes generating a bill of material (BOM) for the circuit, and receiving a user selection of at least one of a computer-aided design (CAD) tool format and a PCB layout tool format. The method also includes receiving a user selection to include footprints for the components used in the schematic content or PCB layout and exporting at least one of the schematic content, and PCB layout as well as the PCB footprints to one or more files in accordance with the selected CAD and/or PCB layout tool format.

10 Claims, 16 Drawing Sheets



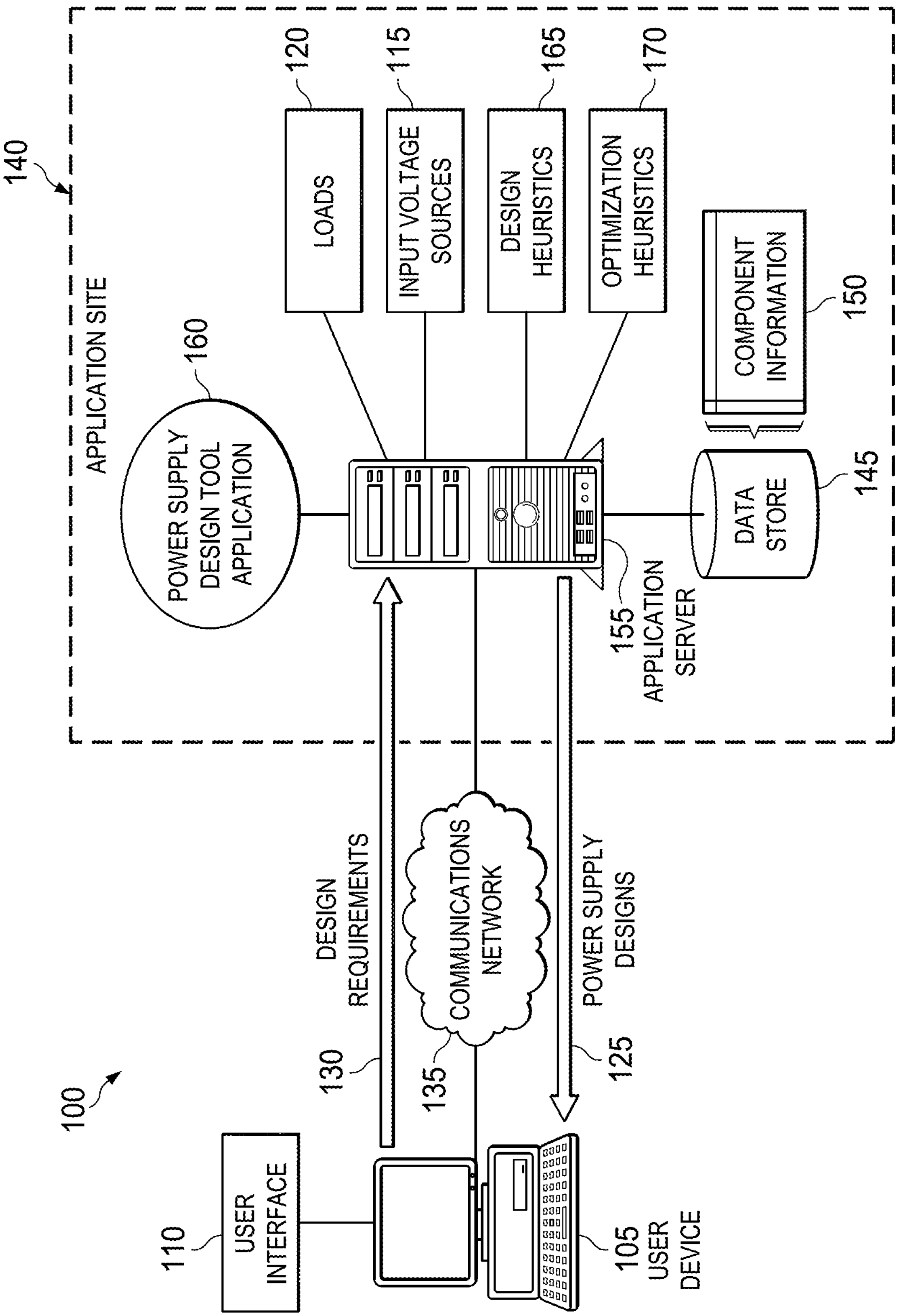

140
APPLICATION SITE
POWER SUPPLY DESIGN TOOL APPLICATION
160
120
LOADS
115
INPUT VOLTAGE SOURCES
165
DESIGN HEURISTICS
170
OPTIMIZATION HEURISTICS
COMPONENT INFORMATION
150
DATA STORE
145
155
APPLICATION SERVER
DESIGN REQUIREMENTS
130
COMMUNICATIONS NETWORK
135
POWER SUPPLY DESIGNS
125
100
USER INTERFACE
110
105
USER DEVICE

FIG. 1

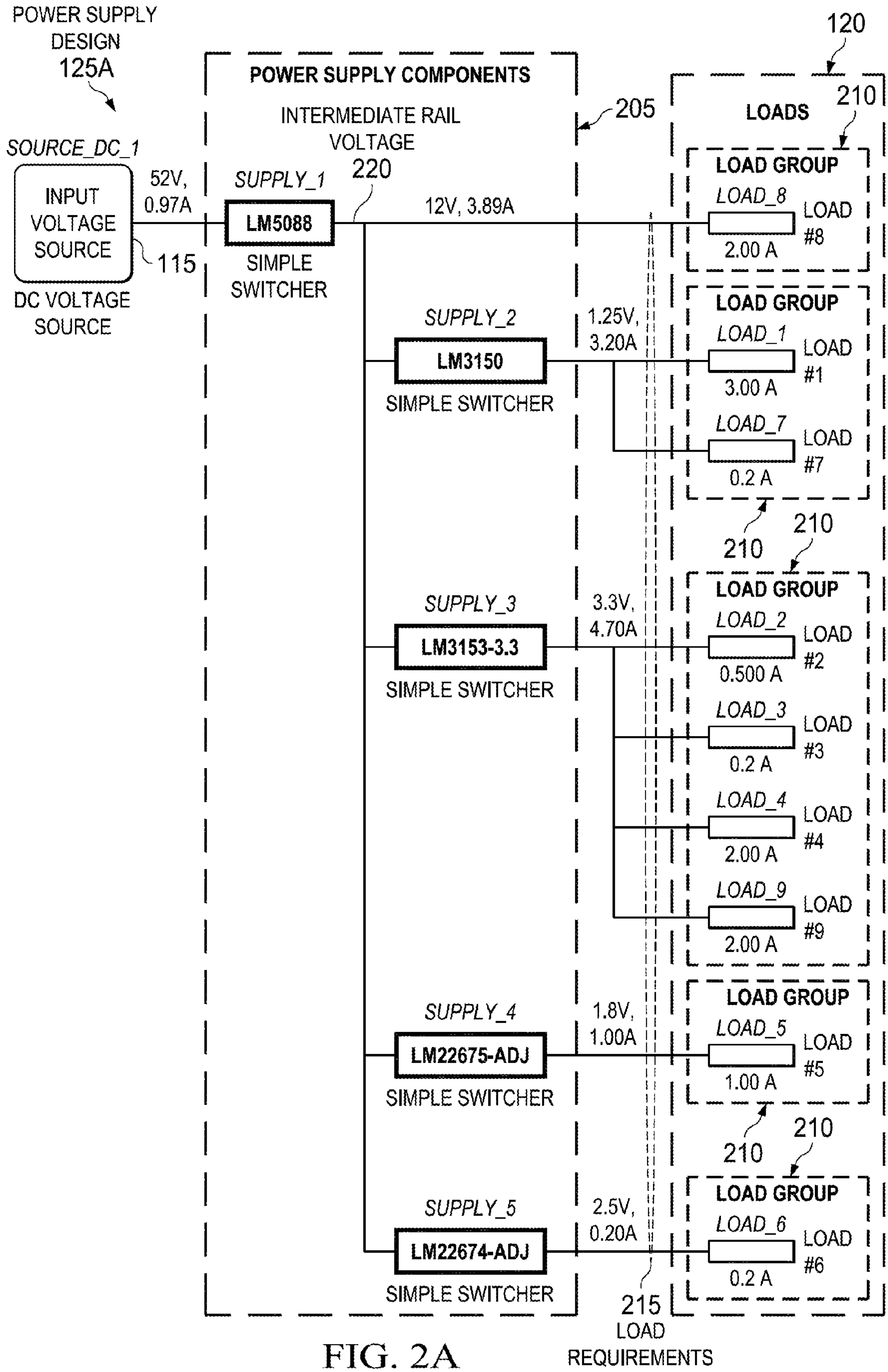

POWER SUPPLY DESIGN
125A
SOURCE_DC_1
INPUT VOLTAGE SOURCE
115
DC VOLTAGE SOURCE
52V, 0.97A
POWER SUPPLY COMPONENTS
INTERMEDIATE RAIL VOLTAGE
220
205
SUPPLY_1
LM5088
SIMPLE SWITCHER
12V, 3.89A
SUPPLY_2
LM3150
SIMPLE SWITCHER
1.25V, 3.20A
SUPPLY_3
LM3153-3.3
SIMPLE SWITCHER
3.3V, 4.70A
SUPPLY_4
LM22675-ADJ
SIMPLE SWITCHER
1.8V, 1.00A
SUPPLY_5
LM22674-ADJ
SIMPLE SWITCHER
2.5V, 0.20A
120
LOADS
210
LOAD GROUP
LOAD_8
LOAD #8
2.00 A
LOAD GROUP
LOAD_1
LOAD #1
3.00 A
LOAD_7
LOAD #7
0.2 A
210
210
LOAD GROUP
LOAD_2
LOAD #2
0.500 A
LOAD_3
LOAD #3
0.2 A
LOAD_4
LOAD #4
2.00 A
LOAD_9
LOAD #9
2.00 A
LOAD GROUP
LOAD_5
LOAD #5
1.00 A
210
210
LOAD GROUP
LOAD_6
LOAD #6
0.2 A
215
LOAD REQUIREMENTS

FIG. 2A

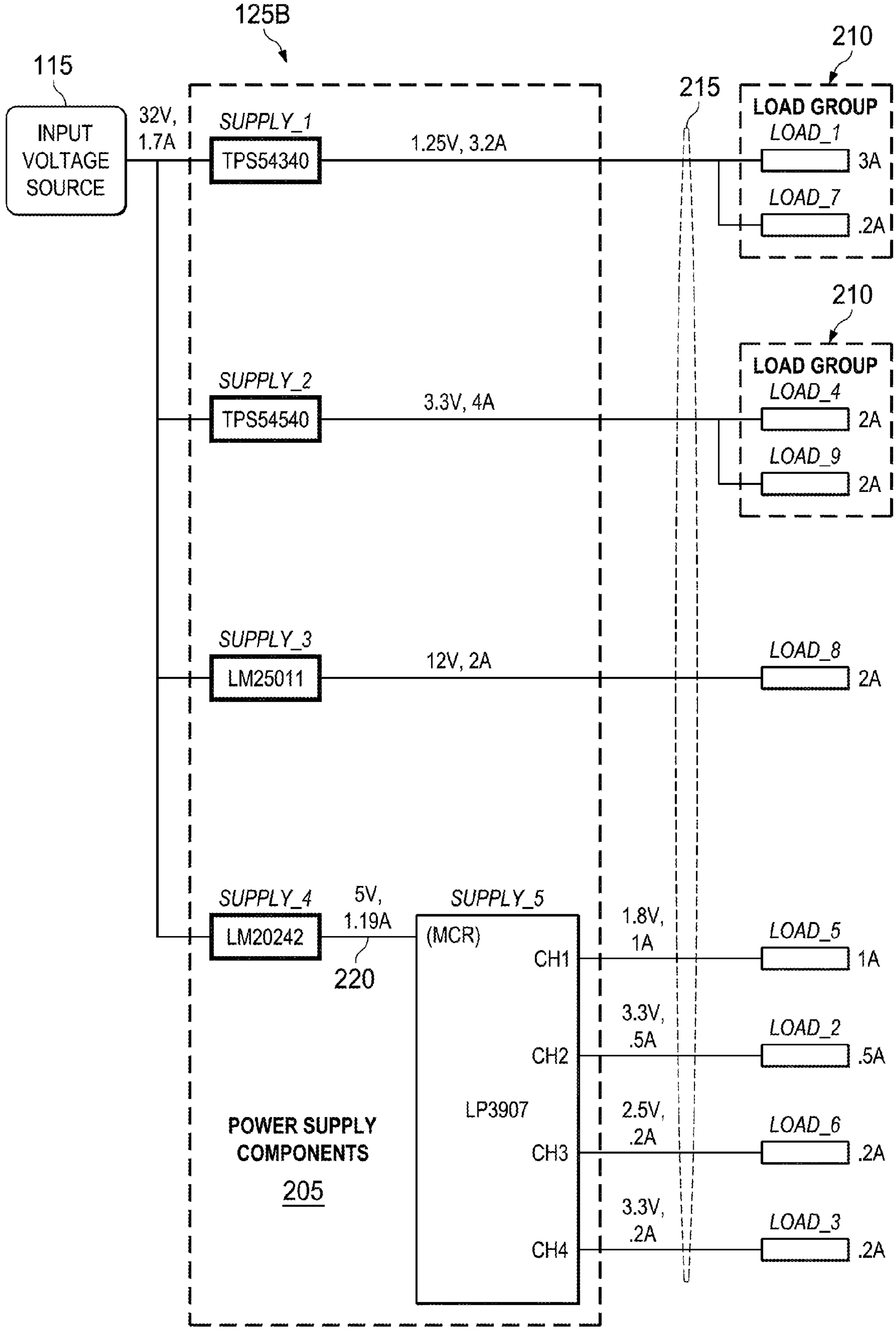

125B
115
INPUT VOLTAGE SOURCE
32V, 1.7A
SUPPLY_1
TPS54340
1.25V, 3.2A
215
210
LOAD GROUP
LOAD_1
3A
LOAD_7
.2A
SUPPLY_2
TPS54540
3.3V, 4A
210
LOAD GROUP
LOAD_4
2A
LOAD_9
2A
SUPPLY_3
LM25011
12V, 2A
LOAD_8
2A
SUPPLY_4
LM20242
5V, 1.19A
220
SUPPLY_5
(MCR)
LP3907
CH1
CH2
CH3
CH4
1.8V, 1A
3.3V, .5A
2.5V, .2A
3.3V, .2A
LOAD_5
1A
LOAD_2
.5A
LOAD_6
.2A
LOAD_3
.2A
POWER SUPPLY COMPONENTS
205

FIG. 2B

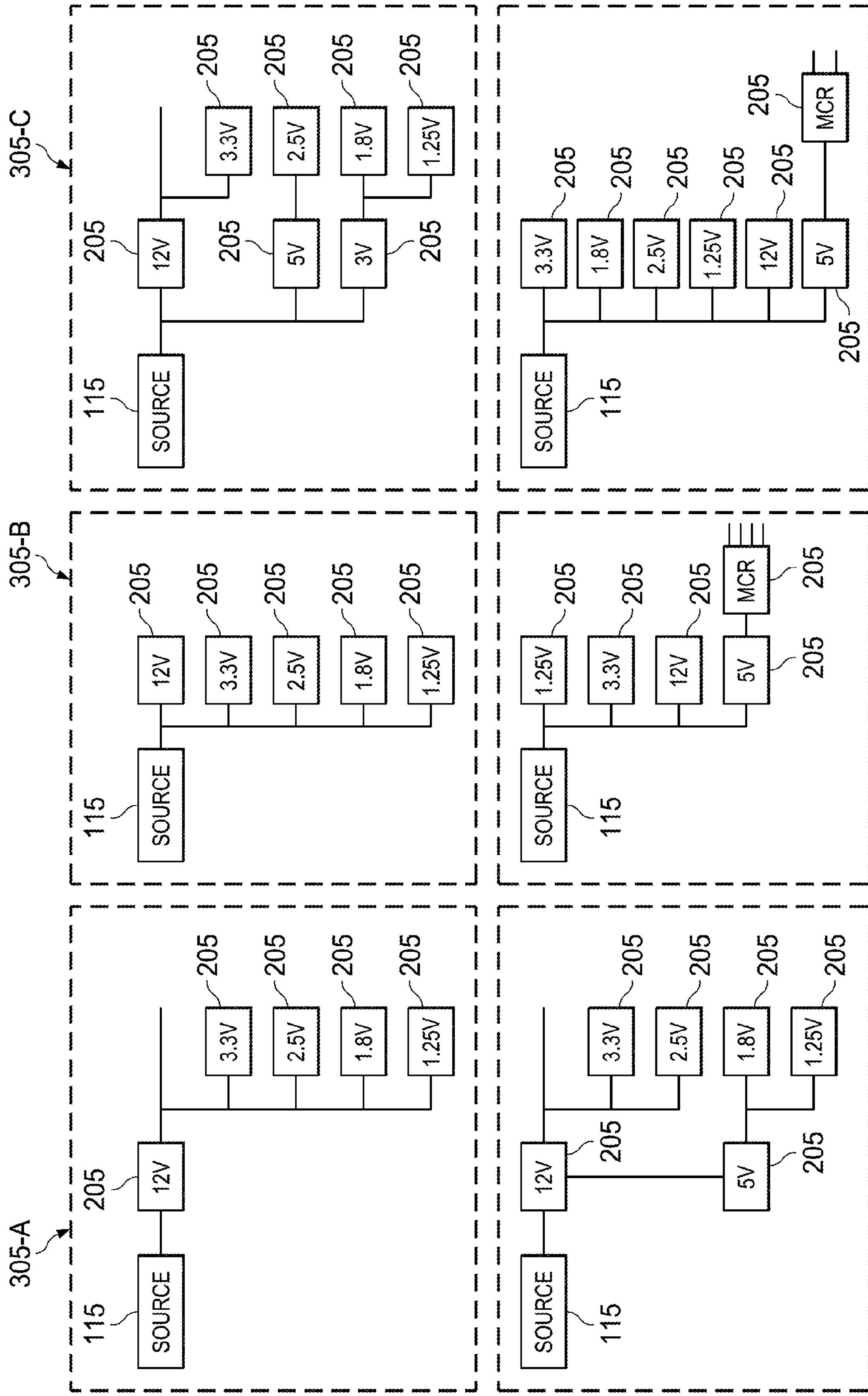

305-A
115
SOURCE
205
12V
3.3V
2.5V
1.8V
1.25V
305-B
305-C
3V
5V
305-D
305-E
MCR
305-F

FIG. 3

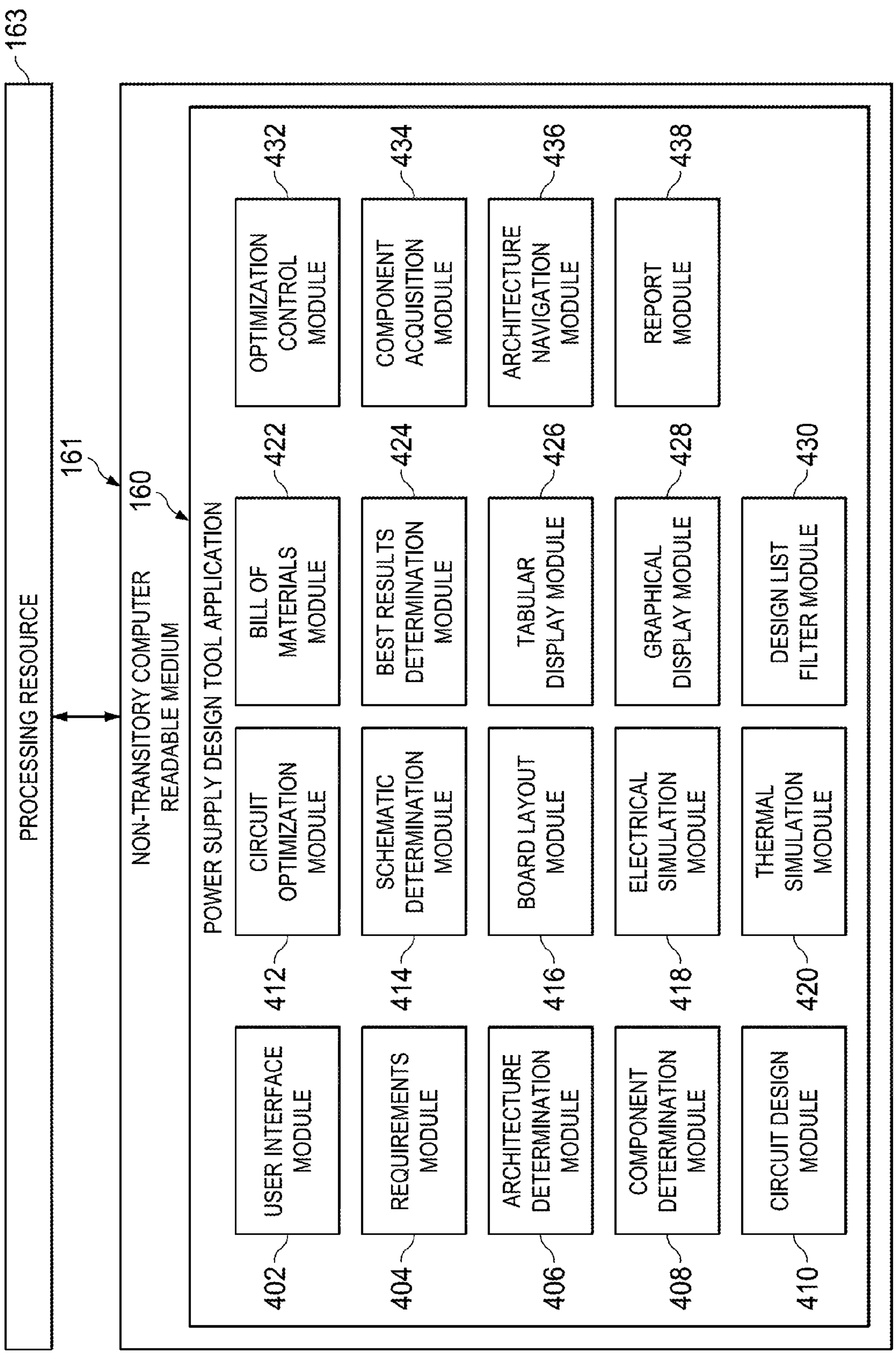

163
PROCESSING RESOURCE
161
NON-TRANSITORY COMPUTER READABLE MEDIUM
160
POWER SUPPLY DESIGN TOOL APPLICATION
402
USER INTERFACE MODULE
404
REQUIREMENTS MODULE
406
ARCHITECTURE DETERMINATION MODULE
408
COMPONENT DETERMINATION MODULE
410
CIRCUIT DESIGN MODULE
412
CIRCUIT OPTIMIZATION MODULE
414
SCHEMATIC DETERMINATION MODULE
416
BOARD LAYOUT MODULE
418
ELECTRICAL SIMULATION MODULE
420
THERMAL SIMULATION MODULE
422
BILL OF MATERIALS MODULE
424
BEST RESULTS DETERMINATION MODULE
426
TABULAR DISPLAY MODULE
428
GRAPHICAL DISPLAY MODULE
430
DESIGN LIST FILTER MODULE
432
OPTIMIZATION CONTROL MODULE
434
COMPONENT ACQUISITION MODULE
436
ARCHITECTURE NAVIGATION MODULE
438
REPORT MODULE

FIG. 4

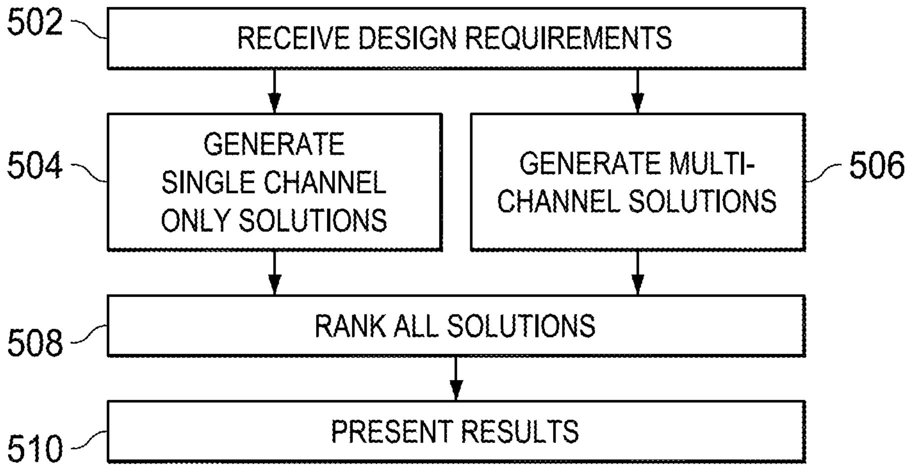

502
RECEIVE DESIGN REQUIREMENTS
504
GENERATE SINGLE CHANNEL ONLY SOLUTIONS
GENERATE MULTI-CHANNEL SOLUTIONS
506
508
RANK ALL SOLUTIONS
510
PRESENT RESULTS

FIG. 5A

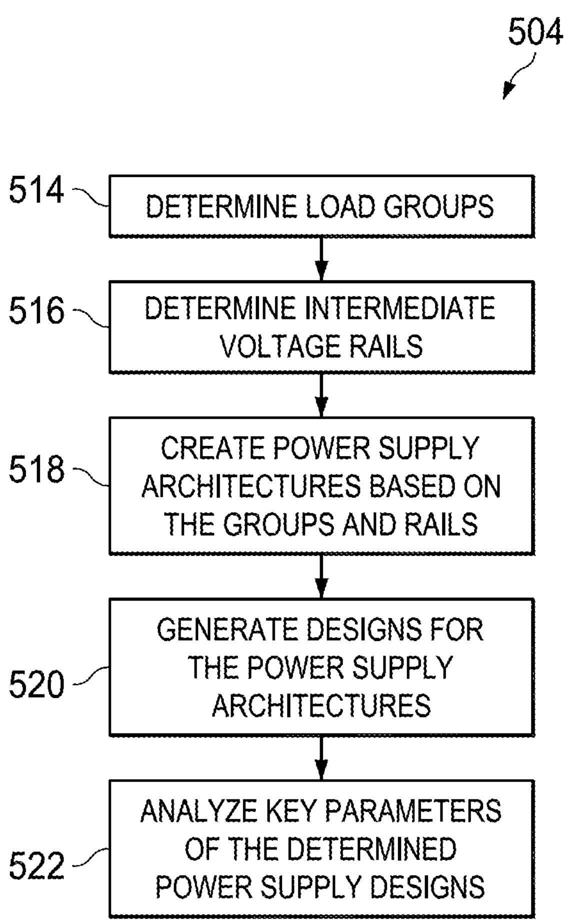

504
514
DETERMINE LOAD GROUPS
516
DETERMINE INTERMEDIATE VOLTAGE RAILS
518
CREATE POWER SUPPLY ARCHITECTURES BASED ON THE GROUPS AND RAILS
520
GENERATE DESIGNS FOR THE POWER SUPPLY ARCHITECTURES
522
ANALYZE KEY PARAMETERS OF THE DETERMINED POWER SUPPLY DESIGNS

FIG. 5B

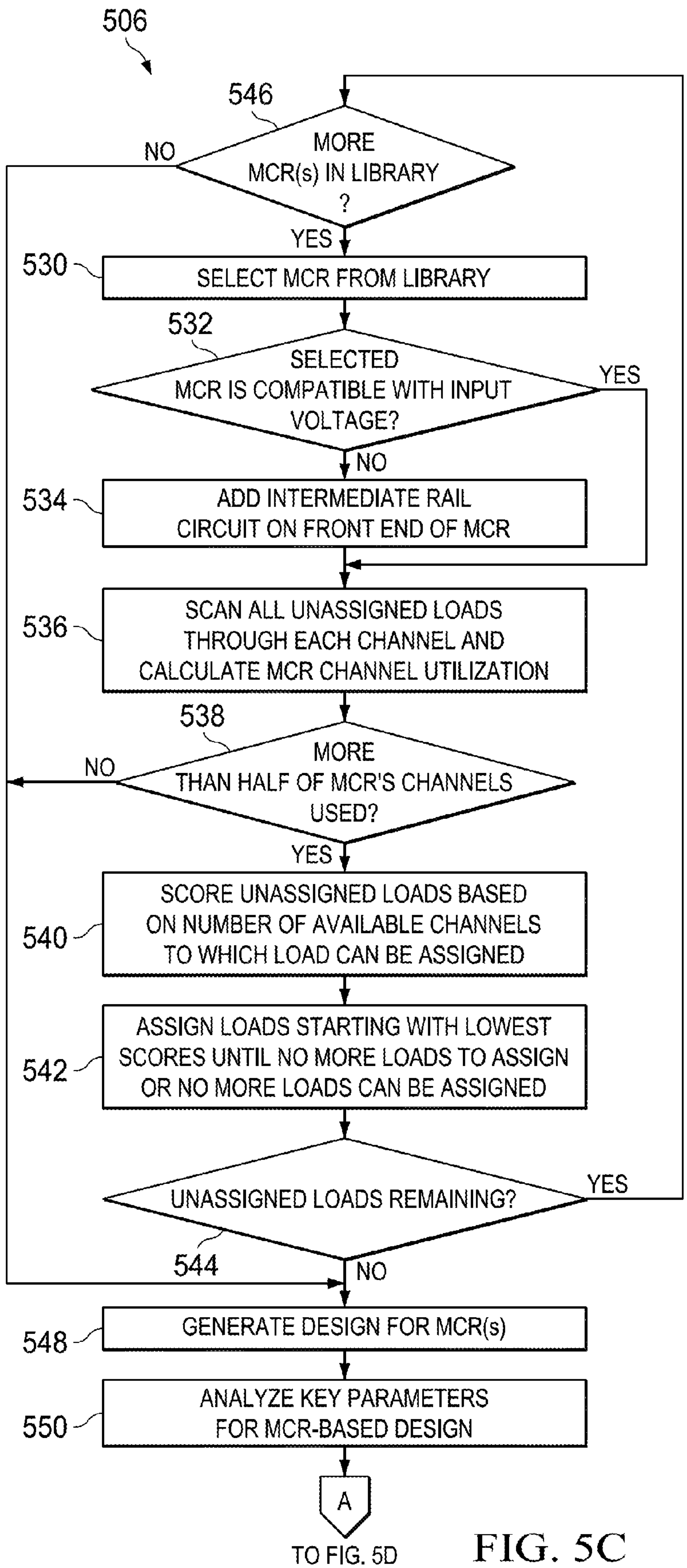

506
546
MORE MCR(s) IN LIBRARY ?
NO
YES
530
SELECT MCR FROM LIBRARY
532
SELECTED MCR IS COMPATIBLE WITH INPUT VOLTAGE?
YES
NO
534
ADD INTERMEDIATE RAIL CIRCUIT ON FRONT END OF MCR
536
SCAN ALL UNASSIGNED LOADS THROUGH EACH CHANNEL AND CALCULATE MCR CHANNEL UTILIZATION
538
MORE THAN HALF OF MCR'S CHANNELS USED?
NO
YES
540
SCORE UNASSIGNED LOADS BASED ON NUMBER OF AVAILABLE CHANNELS TO WHICH LOAD CAN BE ASSIGNED
542
ASSIGN LOADS STARTING WITH LOWEST SCORES UNTIL NO MORE LOADS TO ASSIGN OR NO MORE LOADS CAN BE ASSIGNED
UNASSIGNED LOADS REMAINING?
YES
544
NO
548
GENERATE DESIGN FOR MCR(s)
550
ANALYZE KEY PARAMETERS FOR MCR-BASED DESIGN
A
TO FIG. 5D

FIG. 5C

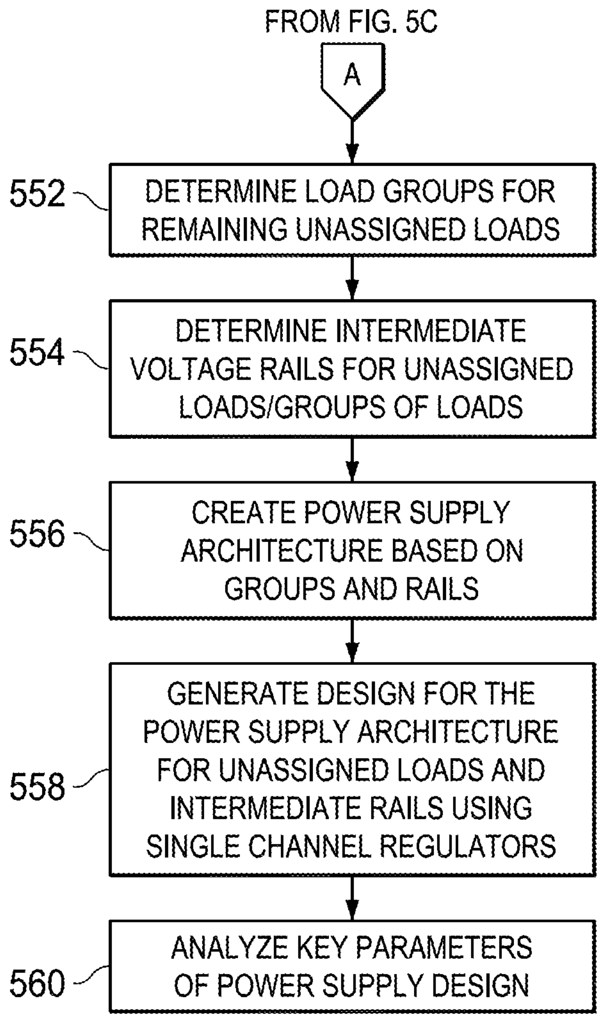

FROM FIG. 5C
A
552
DETERMINE LOAD GROUPS FOR REMAINING UNASSIGNED LOADS
554
DETERMINE INTERMEDIATE VOLTAGE RAILS FOR UNASSIGNED LOADS/GROUPS OF LOADS
556
CREATE POWER SUPPLY ARCHITECTURE BASED ON GROUPS AND RAILS
558
GENERATE DESIGN FOR THE POWER SUPPLY ARCHITECTURE FOR UNASSIGNED LOADS AND INTERMEDIATE RAILS USING SINGLE CHANNEL REGULATORS
560
ANALYZE KEY PARAMETERS OF POWER SUPPLY DESIGN

FIG. 5D

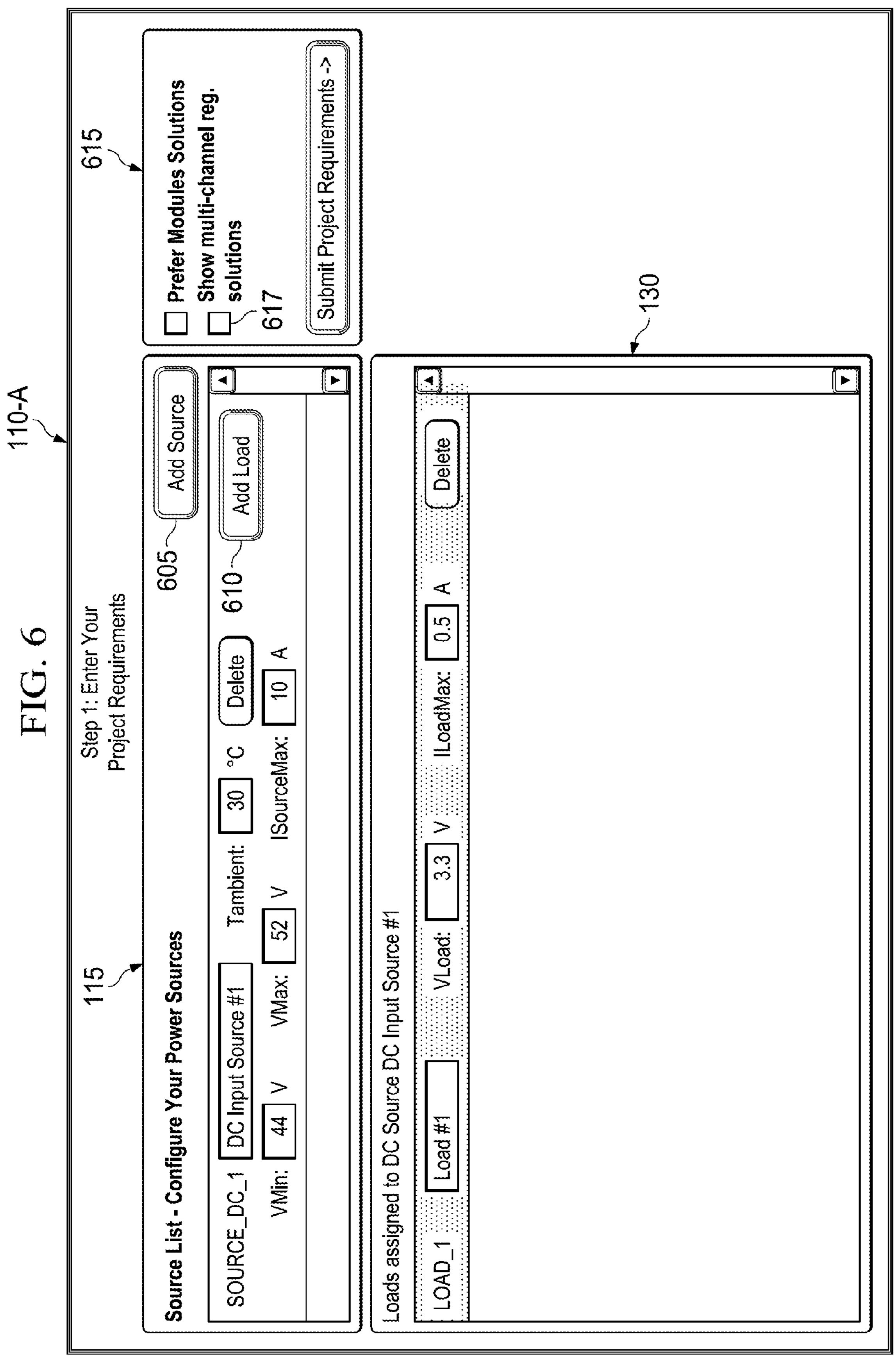

110-A
Step 1: Enter Your
Project Requirements
115
Source List - Configure Your Power Sources
SOURCE_DC_1
DC Input Source #1
Tambient:
30
°C
Delete
VMin:
44
V
VMax:
52
V
ISourceMax:
10
A
605
Add Source
610
Add Load
615
Prefer Modules Solutions
Show multi-channel reg. solutions
617
Submit Project Requirements ->
130
Loads assigned to DC Source DC Input Source #1
LOAD_1
Load #1
VLoad:
3.3
V
ILoadMax:
0.5
A
Delete

FIG. 6

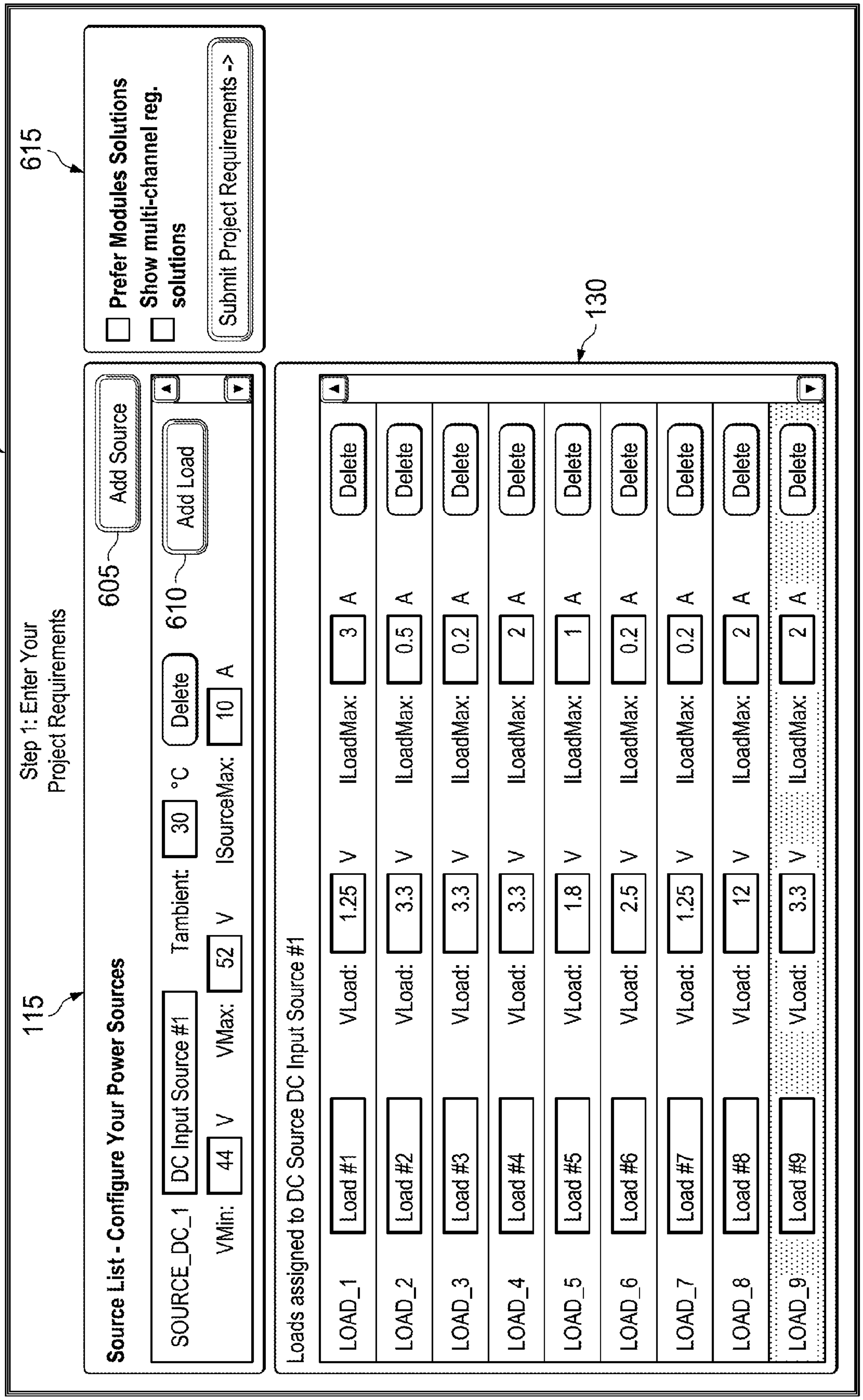

110-B
115
Step 1: Enter Your Project Requirements
Source List - Configure Your Power Sources
SOURCE_DC_1
DC Input Source #1
Tambient:
30
°C
Delete
VMin:
44
V
VMax:
52
V
ISourceMax:
10
A
605
Add Source
610
Add Load
615
Prefer Modules Solutions
Show multi-channel reg. solutions
Submit Project Requirements ->
130
Loads assigned to DC Source DC Input Source #1
LOAD_1 Load #1 VLoad: 1.25 V ILoadMax: 3 A Delete
LOAD_2 Load #2 VLoad: 3.3 V ILoadMax: 0.5 A Delete
LOAD_3 Load #3 VLoad: 3.3 V ILoadMax: 0.2 A Delete
LOAD_4 Load #4 VLoad: 3.3 V ILoadMax: 2 A Delete
LOAD_5 Load #5 VLoad: 1.8 V ILoadMax: 1 A Delete
LOAD_6 Load #6 VLoad: 2.5 V ILoadMax: 0.2 A Delete
LOAD_7 Load #7 VLoad: 1.25 V ILoadMax: 0.2 A Delete
LOAD_8 Load #8 VLoad: 12 V ILoadMax: 2 A Delete
LOAD_9 Load #9 VLoad: 3.3 V ILoadMax: 2 A Delete

FIG. 7

FIG. 8

110-C

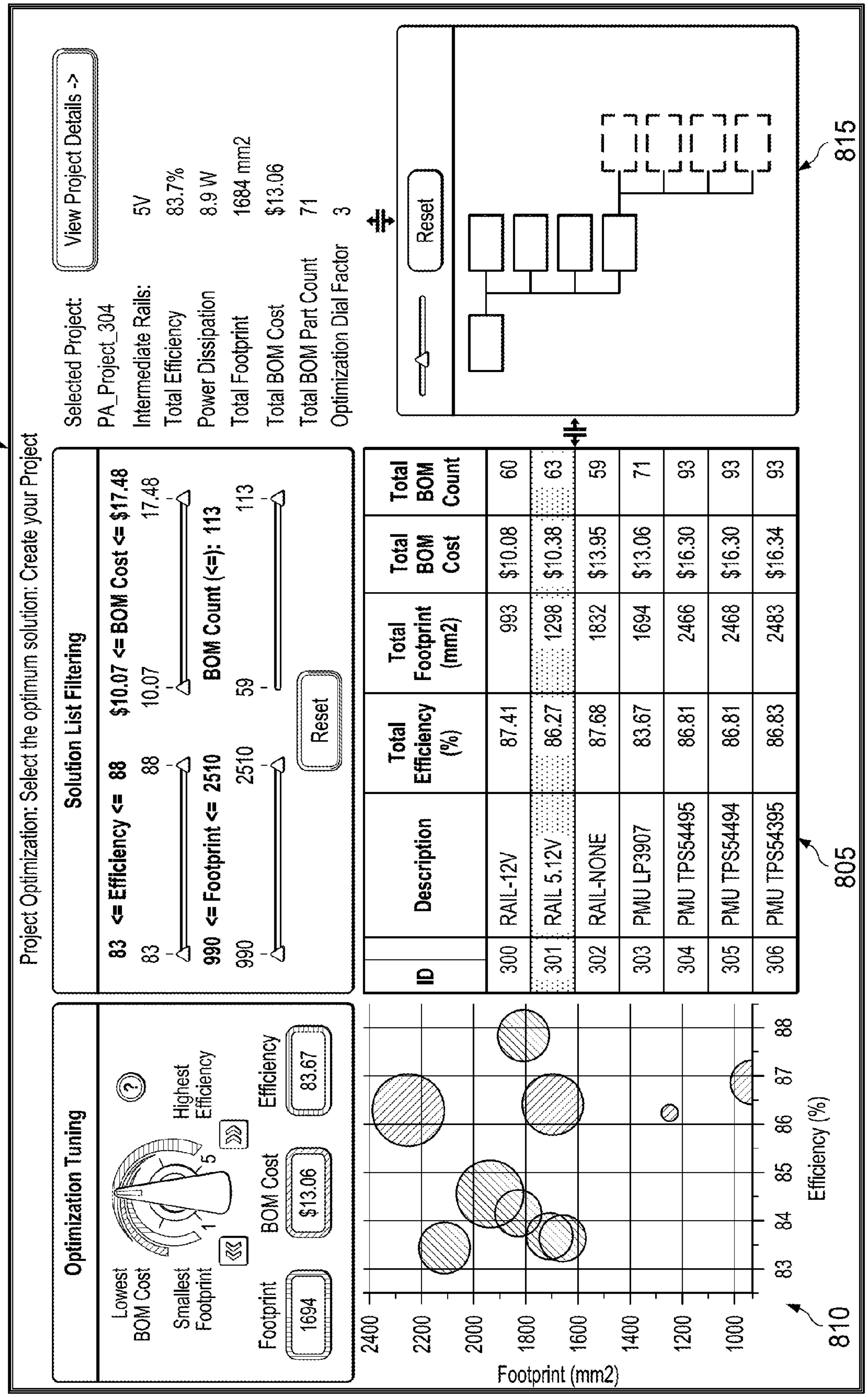

Project Optimization: Select the optimum solution: Create your Project
Optimization Tuning
Lowest BOM Cost
Smallest Footprint
Highest Efficiency
1
5
?
Footprint
1694
BOM Cost
$13.06
Efficiency
83.67
Solution List Filtering
83 <= Efficiency <= 88
83
88
$10.07 <= BOM Cost <= $17.48
10.07
17.48
990 <= Footprint <= 2510
990
2510
BOM Count (<=): 113
59
113
Reset
ID
Description
Total Efficiency (%)
Total Footprint (mm2)
Total BOM Cost
Total BOM Count
300 RAIL-12V 87.41 993 $10.08 60
301 RAIL 5.12V 86.27 1298 $10.38 63
302 RAIL-NONE 87.68 1832 $13.95 59
303 PMU LP3907 83.67 1694 $13.06 71
304 PMU TPS54495 86.81 2466 $16.30 93
305 PMU TPS54494 86.81 2468 $16.30 93
306 PMU TPS54395 86.83 2483 $16.34 93
Selected Project:
View Project Details ->
PA_Project_304
Intermediate Rails: 5V
Total Efficiency 83.7%
Power Dissipation 8.9 W
Total Footprint 1684 mm2
Total BOM Cost $13.06
Total BOM Part Count 71
Optimization Dial Factor 3
Reset
Footprint (mm2)
2400
2200
2000
1800
1600
1400
1200
1000
83
84
85
86
87
88
Efficiency (%)
810
805
815

FIG. 9

110-D

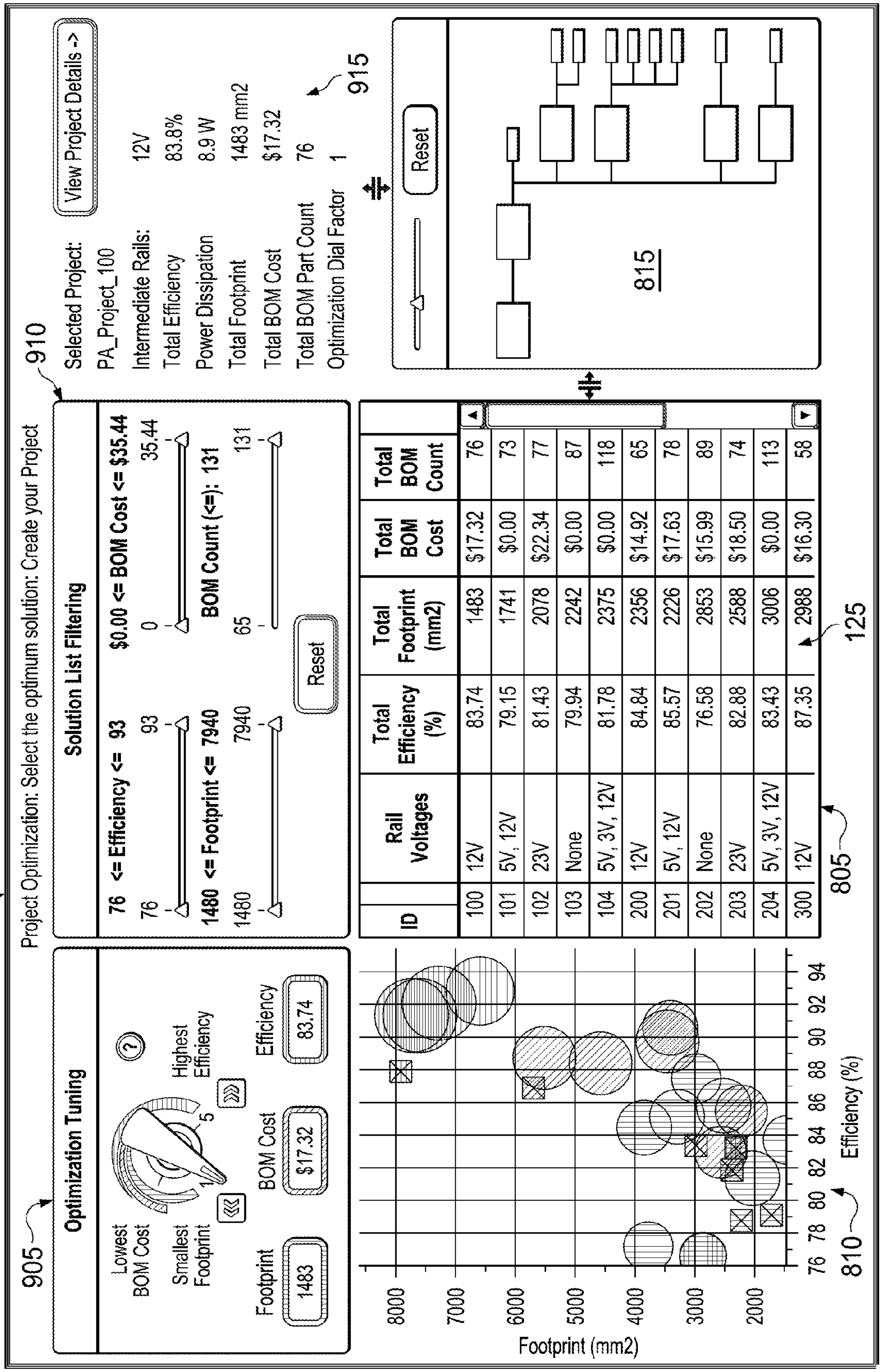
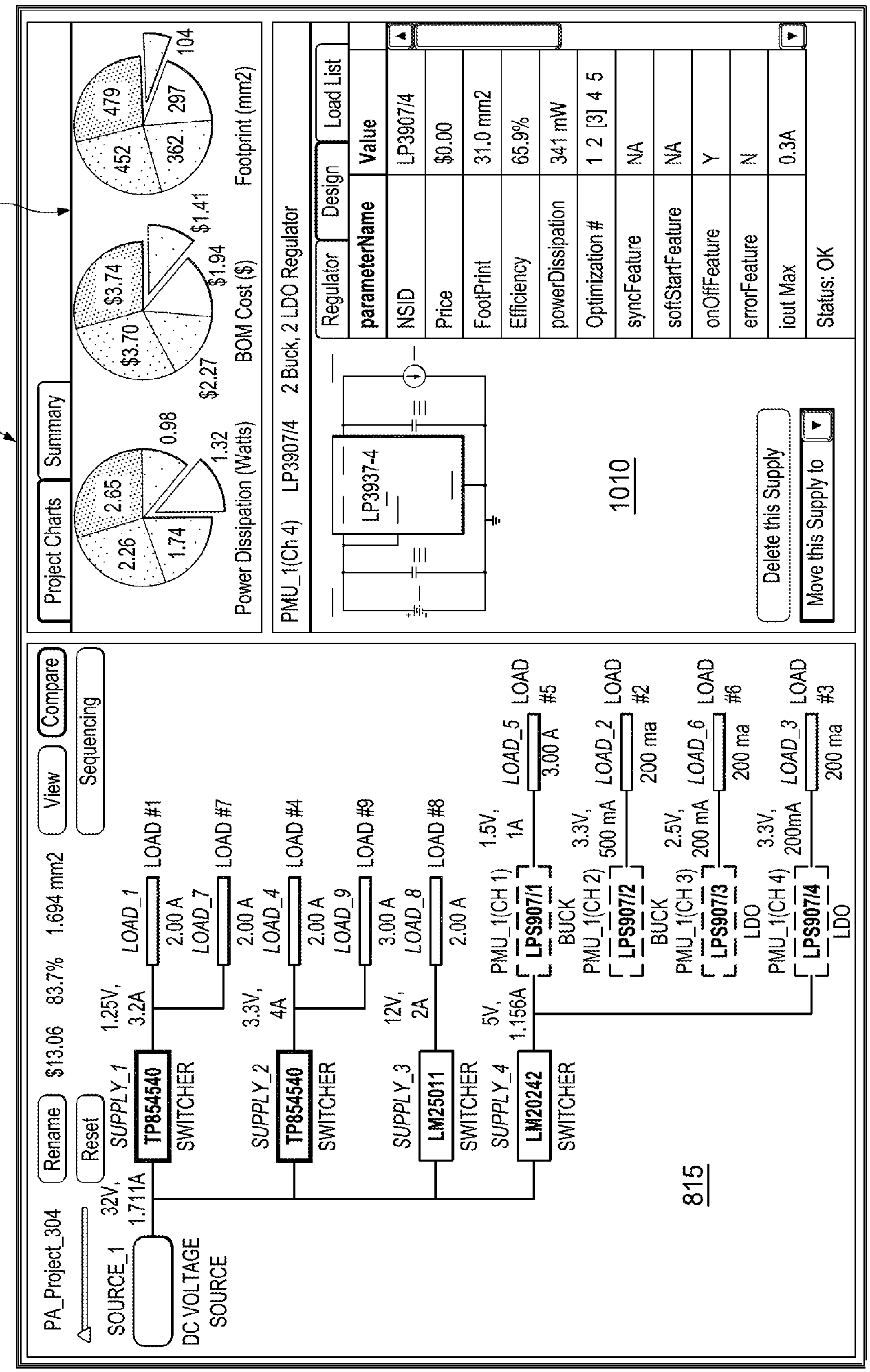

Project Optimization: Select the optimum solution: Create your Project
905
Optimization Tuning
Lowest BOM Cost
Smallest Footprint
Highest Efficiency
Footprint
1483
BOM Cost
$17.32
Efficiency
83.74
910
Solution List Filtering
76 <= Efficiency <= 93
1480 <= Footprint <= 7940
$0.00 <= BOM Cost <= $35.44
BOM Count (<=): 131
Reset
Selected Project:
PA_Project_100
Intermediate Rails: 12V
Total Efficiency 83.8%
Power Dissipation 8.9 W
Total Footprint 1483 mm2
Total BOM Cost $17.32
Total BOM Part Count 76
Optimization Dial Factor 1
View Project Details ->
915
Reset
815
ID
Rail Voltages
Total Efficiency (%)
Total Footprint (mm2)
Total BOM Cost
Total BOM Count
100 12V 83.74 1483 $17.32 76
101 5V, 12V 79.15 1741 $0.00 73
102 23V 81.43 2078 $22.34 77
103 None 79.94 2242 $0.00 87
104 5V, 3V, 12V 81.78 2375 $0.00 118
200 12V 84.84 2356 $14.92 65
201 5V, 12V 85.57 2226 $17.63 78
202 None 76.58 2853 $15.99 89
203 23V 82.88 2588 $18.50 74
204 5V, 3V, 12V 83.43 3006 $0.00 113
300 12V 87.35 2988 $16.30 58
805
125
Footprint (mm2)
Efficiency (%)
810

FIG. 10


110-E
1005
PA_Project_304
Rename
Reset
$13.06 83.7% 1.694 mm2
View
Compare
Sequencing
SOURCE_1
DC VOLTAGE SOURCE
32V, 1.711A
SUPPLY_1
TP854540
SWITCHER
1.25V, 3.2A
LOAD_1
2.00 A
LOAD #1
LOAD_7
2.00 A
LOAD #7
SUPPLY_2
TP854540
SWITCHER
3.3V, 4A
LOAD_4
2.00 A
LOAD #4
LOAD_9
3.00 A
LOAD #9
SUPPLY_3
LM25011
SWITCHER
12V, 2A
LOAD_8
2.00 A
LOAD #8
SUPPLY_4
LM20242
SWITCHER
5V, 1.156A
PMU_1(CH 1)
LPS907/1
BUCK
1.5V, 1A
LOAD_5
3.00 A
LOAD #5
PMU_1(CH 2)
LPS907/2
BUCK
3.3V, 500 mA
LOAD_2
200 ma
LOAD #2
PMU_1(CH 3)
LPS907/3
LDO
2.5V, 200 mA
LOAD_6
200 ma
LOAD #6
PMU_1(CH 4)
LPS907/4
LDO
3.3V, 200mA
LOAD_3
200 ma
LOAD #3
815
Project Charts
Summary
2.26
2.65
1.74
0.98
1.32
Power Dissipation (Watts)
$3.70
$3.74
$2.27
$1.94
$1.41
BOM Cost ($)
452
479
362
297
104
Footprint (mm2)
PMU_1(Ch 4) LP3907/4 2 Buck, 2 LDO Regulator
LP3937-4
1010
Delete this Supply
Move this Supply to
Regulator
Design
Load List
parameterName
Value
NSID
LP3907/4
Price
$0.00
FootPrint
31.0 mm2
Efficiency
65.9%
powerDissipation
341 mW
Optimization #
1 2 [3] 4 5
syncFeature
NA
softStartFeature
NA
onOffFeature
Y
errorFeature
N
iout Max
0.3A
Status: OK

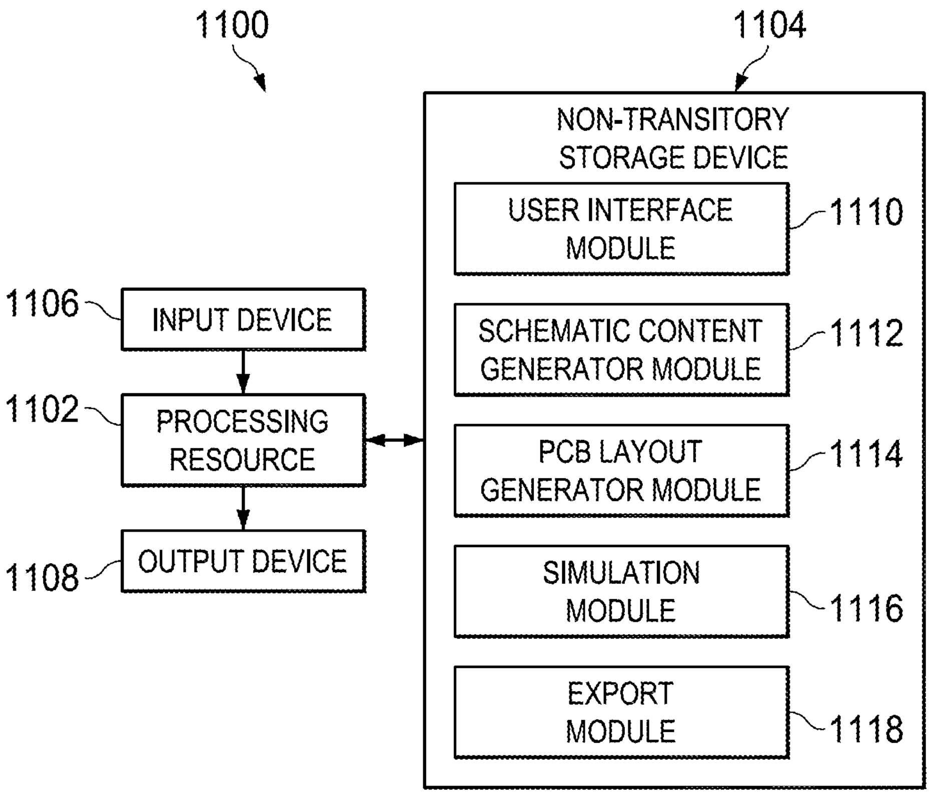

1100
1104
NON-TRANSITORY STORAGE DEVICE
USER INTERFACE MODULE
1110
SCHEMATIC CONTENT GENERATOR MODULE
1112
PCB LAYOUT GENERATOR MODULE
1114
SIMULATION MODULE
1116
EXPORT MODULE
1118
1106
INPUT DEVICE
1102
PROCESSING RESOURCE
1108
OUTPUT DEVICE

FIG. 11

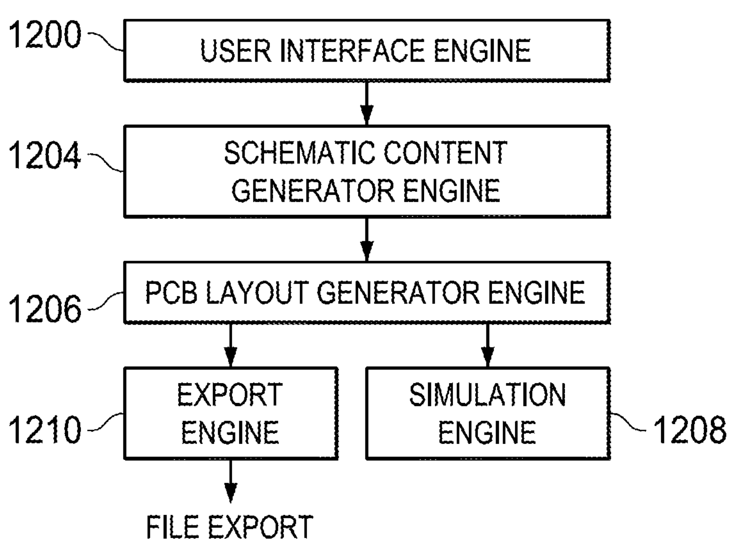

1200
USER INTERFACE ENGINE
1204
SCHEMATIC CONTENT GENERATOR ENGINE
1206
PCB LAYOUT GENERATOR ENGINE
1210
EXPORT ENGINE
SIMULATION ENGINE
1208
FILE EXPORT

FIG. 12

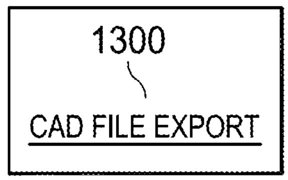

1300
CAD FILE EXPORT

FIG. 13

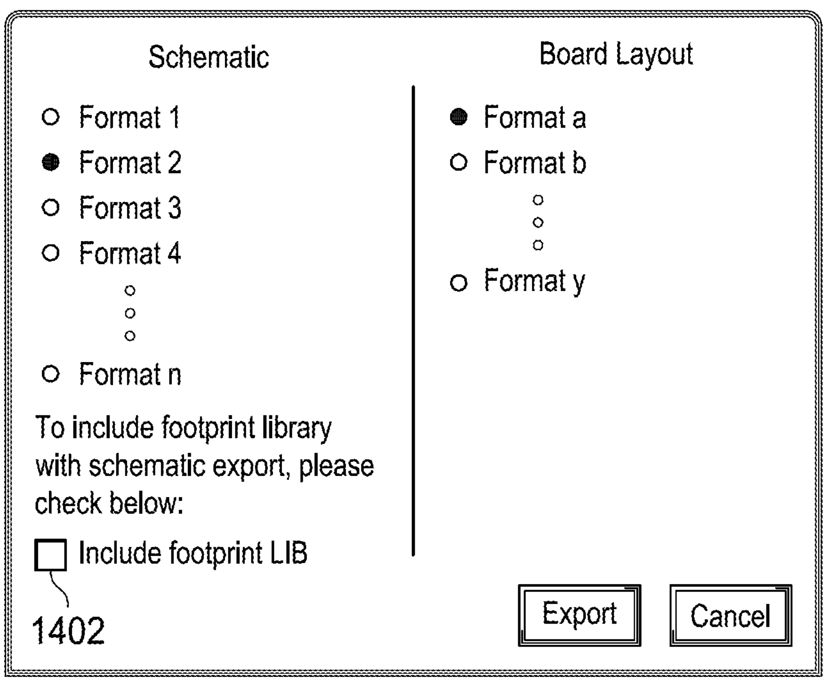

Schematic
Format 1
Format 2
Format 3
Format 4
Format n
To include footprint library with schematic export, please check below:
Include footprint LIB
1402
Board Layout
Format a
Format b
Format y
Export
Cancel

FIG. 14

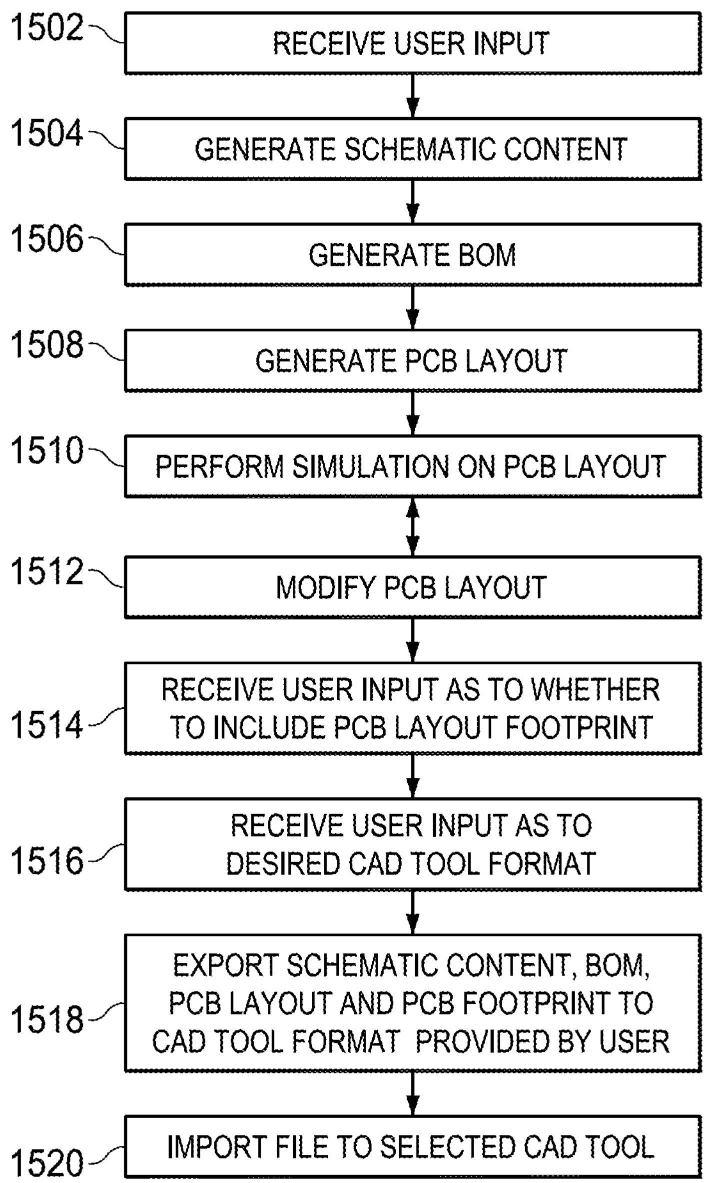

1502
RECEIVE USER INPUT
1504
GENERATE SCHEMATIC CONTENT
1506
GENERATE BOM
1508
GENERATE PCB LAYOUT
1510
PERFORM SIMULATION ON PCB LAYOUT
1512
MODIFY PCB LAYOUT
1514
RECEIVE USER INPUT AS TO WHETHER TO INCLUDE PCB LAYOUT FOOTPRINT
1516
RECEIVE USER INPUT AS TO DESIRED CAD TOOL FORMAT
1518
EXPORT SCHEMATIC CONTENT, BOM, PCB LAYOUT AND PCB FOOTPRINT TO CAD TOOL FORMAT PROVIDED BY USER
1520
IMPORT FILE TO SELECTED CAD TOOL

FIG. 15

CIRCUIT DESIGN SYNTHESIS TOOL WITH EXPORT TO A COMPUTER-AIDED DESIGN FORMAT

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to U.S. Provisional Application No. 61/900,743, titled "System to Synthesize Circuit Designs and Schematic Export to CAD Tools," filed Nov. 6, 2013 and incorporated herein by reference.

BACKGROUND

Electrical circuit designs normally require that a schematic be created in order to document and/or simulate the design. This process is normally performed in a computer aided design (CAD) tool. In addition, the printed circuit board (PCB) layout needs to be created in a CAD tool in order to construct the physical circuit board. In the past, the process of creating an electrical circuit design typically involved first creating the electrical circuit design, including the schematic, bill of materials (BOM) and PCB layout using the user's knowledge, relevant reference materials such as datasheets and application notes, and/or a design synthesis. Then the user unfortunately had to manually enter the schematic and/or printed circuit board (PCB) layout into a CAD tool.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed description of various examples, reference will now be made to the accompanying drawings in which:

FIG. **1** illustrates an exemplary system for determining power supply architectures;

FIGS. **2**A and **2**B illustrate an exemplary power supply design having multiple loads;

FIG. **3** illustrates five exemplary power supply architectures that may be used to power a set of multiple loads;

FIG. **4** illustrates an exemplary modularization of a power supply architecture design tool application;

FIGS. **5**A-**5**D illustrate an exemplary process flow for determining a power supply for multiple loads and including multi-channel regulators;

FIG. **6** illustrates an exemplary user interface for the input of design requirements;

FIG. **7** illustrates an exemplary user interface for the input of design requirements illustrating the inclusion of multiple loads into the design requirements;

FIG. **8** illustrates an exemplary user interface illustrating a set of generated power supply designs;

FIG. **9** illustrates an exemplary user interface illustrating additional generated power supply designs;

FIG. **10** illustrates an exemplary user interface illustrating exemplary project details for one of the power supply designs, including project charts related to key parameters of the one power supply design;

FIG. **11** shows an example of a synthesis design tool to permit a design to be exported to any of a variety of CAD tool formats;

FIG. **12** shows another example of the synthesis design tool of FIG. **11**;

FIGS. **13** and **14** illustrate graphical user interfaces implemented by the synthesis design tool in accordance with a preferred embodiment; and

FIG. **15** shows a method for synthesizing a circuit and PCB layout design and exporting the design to particular CAD tool format in accordance with a preferred embodiment.

DETAILED DESCRIPTION

This disclosure pertains to a design synthesis tool that permits a user to design a circuit to produce a circuit schematic and generate a PCB layout. The tool further permits a user to select any of multiple CAD and PCB layout tool formats and then exports the circuit schematic and PCB layout to the specified CAD and PCB layout tool formats. Once exported, the user then can easily import the files to the CAD tools of his choosing (presumably a CAD tool having the previously selected tool formats), thereby negating the need for the user to re-enter the circuit schematic and PCB layout.

The particular circuit being designed by the design synthesis tool can be any circuit of the user's choosing. Unless otherwise stated, no limitation is placed herein on the circuit itself being designed or how the design synthesis tool permits a user to design the circuit. An example of the use of a design synthesis tool to design a power supply circuit is provided below merely for purposes of an example. Following this example, a discussion is provided of the export capabilities of the design synthesis tool.

Circuit Design Example—Power Supply

The design of a power supply is a function of the input voltage(s) and the desired output voltages. A power supply can be designed for a single load or for multiple loads. Single channel or multiple channel voltage regulators can be used. For a single load, a manufacturer of power supply components may be able to supply on the order of dozens of possible designs that satisfy a given set of power supply requirements. These design solutions may include various power supply components and supporting components to allow the power supply components to function for the particular application. Additionally, these different design solutions may take up different footprints, have different electrical efficiency ratings, and have different component costs. Some design solutions may include single channel only voltage regulators, while other design solutions include multi-channel voltage regulators or even a combination of single channel and multi-channel voltage regulators

Multiple design solutions may be possible for a given set of loads and power supply requirements including various combinations of voltage and current ratings. The disclosed design tool permits a user to quickly and efficiently determine the various design solutions including at least multi-channel voltage regulators. The design tool also permits efficient comparison of each of the designs solutions by hand to determine an appropriate power supply design to satisfy the user's needs.

The disclosed design tool is configured to generate solutions on a dynamic basis, based on a request for solutions configured to power a set of multiple loads. Designing power supply systems that use multi-channel voltage regulators can be an overwhelming task due to the large number of such devices on the market and the even large number of possible designs that may use a combination of single channel and multi-channel voltage regulators. Thus, the design tool automatically proposes design solutions that include multi-channel voltage regulators, thereby alleviating the burden on the system designer. The design tool may utilize various heuristics to selectively group the multiple loads, determine potential intermediate voltage rails, and dynamically compute a multitude of power supply design architectures that can power the set of load requirements. Each power supply architecture may include positions at which components configured to satisfy the load requirements are to be determined. In at least some of the computed power supply design architectures, a multi-channel voltage regulator is included in at least one of the positions of each such architecture. Using the generated power supply design architectures and a database of component information, the design tool may utilize various heuristics to determine components to use to implement the power supply design architectures in light of design goals for the solutions, and may generate a set of different solutions that each are capable of powering the set of multiple loads.

Components may be added or removed from the database of component information to allow for the dynamic creation of different solutions. Further, because the solutions are created dynamically upon user request, the generated solutions are always up-to-date based on the component information in the database. In some instances, the design tool may be configured to prefer components from one or more vendors, manufacturers, or suppliers.

The design tool may further optimize the generated designs in accordance with additional design parameters indicating a tradeoff between various optimizations, such as power supply efficiency, component and printed circuit board footprint size, and overall component cost. The design tool may also provide a capability for graphical comparison and analysis of the resulting design solutions. Through use of the design tool, a user may quickly design and optimize a power supply configured to power a set of multiple loads and customized to the user's needs.

FIG. **1** illustrates an exemplary system **100** for determining power supply solutions for multiple power supply loads. As illustrated in FIG. **1** the exemplary system includes a user device **105** configured to provide a user interface **110** where the user interface **110** is configured to receive design requirements **130** relating to at least one input voltage source **115** and a plurality of loads **120** and display a set of power supply designs **125**. The system **100** further includes a communications network **135** in selective communication with the user device **105** and an application site **140**. The application site **140** includes a data store **145** configured to store component information **150**. The application site **140** further includes an application server **155** configured to run a power supply design tool application **160**. The power supply design tool application **160** may receive the design requirements **130**, and may produce the set of power supply designs **125** responsive to the design requirements **130**, relevant design heuristics **165** and optimization heuristics **170**, as well as selected component information **150** from the data store **145**. System **100** may take many different forms and include multiple and/or alternate components and facilities. While an exemplary system **100** is shown in FIG. **1**, the exemplary components illustrated in FIG. **1** are not intended to be limiting. Indeed, additional or alternative components and/or implementations may be used.

The user device **105** may be a device configured to be operated by one or more users, such as a cellular telephone, laptop computer, tablet computing device, personal digital assistant, or desktop computer workstation, among others. The user device **105** may include one or more components capable of receiving input from a user (e.g., via a keyboard, mouse, etc.), and providing output to the user (e.g., a display).

The user interface **110** may be an interface configured to allow for the effective operation and control of the user device **105**. The user interface **110** may further provide feedback and other output to the user to aid the user in making operational decisions with respect to the user device **105**. Exemplary user interfaces **110** may include input devices such as keyboards, buttons, and microphones, and output devices such as display screens and loudspeakers. As a particular example, a user interface **110** may be implemented by way of one or more web pages displayed by the user device **105** by way of a web browser software program. Such a web-based user interface **110** may accept input from a user by way of one or more controls on a web page and may provide output by displaying web pages to the user including feedback or other outputs of the system **100**. As another example, a user interface **110** may be implemented by way of a self-contained rich internet application (RIA) utilizing an engine such as Adobe Flash, where the RIA may accept input from a user by way of one or more controls and provide output that may be viewed by the user on the user device **105**.

An input voltage source **115** may be a device or system that produces or derives an electromotive force between its terminals. Input voltage sources **115** may be defined according to the voltage and maximum current draw they provide, and may further be defined according to a name to aid in identification. A load **120** may be an electrical device or circuit that requires electrical power to operate. Loads **120** may be defined as a required voltage and maximum current draw. Loads **120** may further be defined according to a name or other identifier to aid in their identification. A power supply may be a source of electrical power, and a power supply design **125** may be a circuit including various components that draw power from one or more input voltage sources **115** and supply electrical energy to at least one load **120**.

The design requirements **130** may include information regarding a set of multiple loads **120** to be powered by one or more input voltage sources **115**. The information may include minimum, maximum, and nominal input voltage, ambient temperature, maximum input current, and other design inputs about one or more input voltage sources **115**. The information may also include details of the loads **120** to be powered, such as a required voltage, a required current, a name or other identifier, and other power supply attributes of the loads **120**.

The communications network **135** may include a mixture of wired (e.g., fiber and copper) and wireless mechanisms that incorporate related infrastructure and accompanying network elements. Illustrative communication networks **135** may include the Internet, an intranet, the Public Switched Telephone Network (PSTN), and a cellular telephone network. The communications network **135** may include multiple interconnected networks and/or sub-networks that provide communications services, including data transfer and other network services to at least one user device **105** connected to the communications network **135**.

The communications network **135** may be in selective communication with an application site **140**. The application site **140** may be a hosting platform, such as a web hosting platform, configured to make applications available over the communications network **135**. To perform the hosting functions, the application site **140** may include computing devices such as one or more data stores **145** and application servers **155**.

The data store **145** may include one or more data storage mediums, devices, or configurations, and may employ various types, forms, and/or combinations of storage media, including but not limited to hard disk drives, flash drives, read-only memory, and random access memory. The data store **145** may include various technologies useful for storing and accessing any suitable type or form of electronic data, which may be referred to as content. Content may include computer-readable data in any form, including, but not limited to video, image, text, document, audio, audiovisual, metadata, and other types of files or data. Content may be stored in a relational format, such as via a relational database management system (RDBMS). As another example, content may be stored in a hierarchical or flat file system. In particular the data store **145** may store content including component information **150**. Notably, the data store **145** maintains information with respect to individual components, not completed designs, solutions, or formulations.

The component information **150** may include information on the individual components, such as power supply regulators (switching regulators, low drop out regulators (LDOs), switched capacitors or other types of voltage regulators), capacitors, resistors, diodes, etc. The voltage regulators may include single channel voltage regulators and multi-channel voltage regulators. Component information **150** may be received from manufacturers or suppliers in various forms, such as parts information sheets, parts catalogs, schematics, among others. The received component information **150** may be formatted and saved into the data store **145** for use in determining designs. Exemplary component information **150** may include part cost, whether the part is in stock, part dimensions and footprint, pin configuration, minimum and maximum ranges of operation, light output, heat sink requirements, efficiency information, graphs of various characteristics of operation, what manufacturers produce the component (or an equivalent component) and what suppliers or vendors supply the component, among other exemplary characteristics. For a multi-channel regulator, for example, the component information may include the number of channels and, for each channel, the range of operating voltages and current. The component information **150** includes information about the components themselves, not the components in combination with other components.

The application site **140** may further include an application server **155**. The application server **155** may be implemented as a combination of hardware and software, and may include one or more software applications or processes for causing one or more computer processors to perform the operations of the application server **155** described herein.

A power supply design tool application **160** may be one application included on the application server **155**, wherein the power supply design tool application **160** may be implemented at least in part by instructions stored on one or more non-transitory computer-readable media. The power supply design tool application **160** may include instructions to cause the application server **155** to receive design requirements **130** indicating a set of multiple loads **120**, query the data store **145** for component information **150** related to the design requirements **130**, produce a set of power supply designs **125** responsive to the design requirements **130** and component information **150**, and return the power supply designs **125** for further analysis and use.

The power supply design tool application **160** may utilize design heuristics **165** when determining the set of power supply designs **125** responsive to the design requirements **130**. Design heuristics **165** may include rules related to the generation of different power supply architectures which may be appropriate to power the loads **120** specified by the design requirements **130**. The design heuristics **165** may allow for the generation of a plurality of power supply architectures indicating potential arrangements of components between the one or more input voltage sources **115** and the plurality of loads **120** specified by the design requirements **130**. For example, a design heuristic **165** may be utilized to identify a multi-channel voltage regulator to be used in a given power supply architecture. By way of another example, a design heuristic **165** may be utilized to determine intermediate rail voltages for possible power supply architectures. As another example, a design heuristic **165** may be utilized to break down the plurality of loads **120** specified by the design requirements **130** into one or more groups with smaller total currents.

The power supply design tool application **160** may utilize optimization heuristics **170** when determining the set of power supply designs **125** responsive to the design requirements **130**. These optimizations may guide the determination of some or even all of the components **205** and supporting component of the power supply designs **125**. Optimization heuristics **170** may be responsive to parameters indicative of tradeoffs between various design goals, and may be utilized to prefer one or more parameters over other parameters of a component or design. Design goals to be optimized by optimization heuristics **170** may include small component footprint, efficiency, cost, thermal dissipation, and power utilized, among others. As an example, an optimization heuristic **170** for designs with a smaller footprint may optimize for size by choosing components with relatively smaller footprints that still satisfy the design requirements **130**, but at the expense of other parameters such as efficiency. As another example, an optimization heuristic **170** for designs with a higher efficiency may optimize by choosing components capable of being utilized at a relatively higher switching frequency while still satisfying the design requirements **130**, but at the expense of other parameters such as cost. Optimization heuristics **170** may further be utilized by the power supply design tool application **160** to give preferred treatment to at least one component unrelated to its electrical or physical characteristics. The optimization heuristics **170** may be applied be a subset of components or even to all components. For example, an optimization heuristic **170** may prefer components from a particular manufacturer or supplier over those from another manufacturer or supplier.

Computer-executable instructions may be compiled or interpreted from computer programs created using a variety of well-known programming languages and/or technologies, including, without limitation, and either alone or in combination, Java™, C, C++, Visual Basic, Java Script, Perl, PL/SQL, etc. The power supply design tool application **160** may accordingly be written at least in part according to a number of these and other programming languages and technologies, or a combination thereof

In some instances, the power supply design tool application **160** is provided as software that when executed by a processor of the application server **155** provides the operations described herein. Alternatively, the power supply design tool application **160** may be provided as hardware or firmware, or combinations of software, hardware and/or firmware. An exemplary modularization of the power supply design tool application **160** is discussed in further detail below with respect to FIG. **4**.

In general, computing systems and/or devices, such as user device **105**, application server **155**, and data store **145** may employ any of a number of well-known computer operating systems, including, but by no means limited to, known versions and/or varieties of the Microsoft Windows® operating system, the Unix operating system (e.g., the Solaris® operating system distributed by Sun Microsystems of Menlo Park, Calif.), the AIX UNIX operating system distributed by International Business Machines of Armonk, N.Y., and the Linux operating system. Examples of computing devices include, without limitation, a computer workstation, a server, a desktop, notebook, laptop, or handheld computer, or some other known computing system and/or device.

Computing devices, such as data store **145** and application server **155** generally include computer-executable instructions, where the instructions may be executable by one or more computing devices such as those listed above. In general, a processor (e.g., a microprocessor) receives instructions, e.g., from a non-transitory computer-readable medium such as memory and executes these instructions, thereby performing one or more processes, including one or more of the processes described herein. Such instructions and other data may be stored and transmitted using a variety of known computer-readable media.

A non-transitory computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory (e.g., tangible) medium that participates in providing data (e.g., instructions) that may be read by a computer (e.g., by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media and volatile media. Non-volatile media may include, for example, optical or magnetic disks and other persistent memory. Volatile media may include, for example, dynamic random access memory (DRAM), which typically constitutes a main memory. Such instructions may be transmitted by one or more transmission media, including coaxial cables, copper wire and fiber optics, including the wires that comprise a system bus coupled to a processor of a computer. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

Databases, data repositories or other data stores, such as such as data store **145** described herein, may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), etc. Each such data store is generally included within a computing device employing a computer operating system such as one of those mentioned above, and are accessed via a network in any one or more of a variety of manners, as is known. A file system may be accessible from a computer operating system, and may include files stored in various formats. An RDBMS generally employs the known Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures, such as the PL/SQL language mentioned above.

In some examples, system elements may be implemented as computer-readable instructions (e.g., software) on one or more computing devices (e.g., servers, personal computers, etc.), stored on computer readable media associated therewith (e.g., disks, memories, etc.). A computer program product may comprise such instructions stored on computer readable media for carrying out the functions described herein.

While FIG. **1** illustrates an exemplary system **100**, other implementations may be used. In some implementations, the system **100** may be implemented as an off-line or self-contained computing device based configuration. In such an implementation, the application server **155** and power supply design tool application **160** may be implemented by a back-end calculation engine running on the computing device. In some implementations, the power supply design tool application **160** may be executed by way of a self-contained RIA utilizing an engine such as Adobe Flash. For example, the RIA may be downloaded by a client from a server by way of a network such as the Internet or an intranet, and where most or substantially all of the calculations performed by the system **100** may be performed on the client using the RIA, without need to go back to the server again during a design session.

Further, additional elements may be included or elements shown in FIG. **1** may be omitted or modified. For example, one or more of the user device **105**, data store **145**, and application server **155** may be combined in certain implementations. As another example, a system may include multiple data stores **145** and/or application servers **155**. In still further examples, power supply design tool application **160** may be implemented across multiple application servers **155**. While communications network **135** is shown in the illustrated embodiment, in other embodiments the communications network **135** may be omitted entirely and the user device **105** may be connected directly to the application site **140**. In still other examples, the power supply design tool application **160** may be executed in whole or in part by the user device **105**.

FIG. **2**A illustrates an exemplary power supply design **125**A that may be used to power an exemplary set of multiple loads **120**. As shown in FIG. **2**A, the exemplary power supply design **125**A is powered by a single input voltage source **115**, and provides power to the following set of loads **120**: a first load **120** (LOAD_1) requiring 1.25V at 3 A, a second load **120** (LOAD_2) requiring 3.3V at 0.5 A, a third load **120** (LOAD_3) requiring 3.3V at 0.2 A, a fourth load **120** (LOAD_4) requiring 3.3V at 2 A, a fifth load **120** (LOAD_5) requiring 1.8V at 1 A, a sixth load **120** (LOAD_6) requiring 2.5V at 0.2 A, a seventh load **120** (LOAD_7) requiring 1.25V at 0.2 A, an eighth load **120** (LOAD_8) requiring 12V at 2 A, and a ninth load **120** (LOAD_9) requiring 3.3V at 2 A. The power supply design **125** further illustrates the grouping of the multiple loads **120** into load groups **210**, as well as the determined load requirements **215** for each load group **210** and intermediate rail voltage **220**. It should be noted that the exemplary power supply design **125** is only one of many possible power supply designs **125** that may be used to power the illustrated multiple loads **120**.

A power supply component **205** may be a component such as a switching regulator controller configured to provide a regulated output at a specified voltage and current. A power supply component **205** may accordingly provide a regulated output at the specified voltage for up to a maximum amount of current. The power supply components in the illustrative power supply design **125**A of FIG. **2**A include single-channel voltage regulators, that is a regulator with only a single regulated output voltage.

Because a power supply component **205** may provide a regulated output at a particular voltage, multiple loads **120** that share a common voltage may be grouped and accordingly powered from the same power supply component **205**, provided that the power supply component **205** can supply the necessary current. A load group **210** is a grouping of one or more loads **120** according to common voltage. A load requirement **215** includes the requirements for the powering of a corresponding load group **210**. For example, the load requirement **215** for a load group **210** may be determined according to the common voltage of the group and a sum of the currents of each load **120** of the load group **210**.

For example, as shown in FIG. **2**A, the first load **120** requires 1.25V at 3 A and the seventh load **120** requires 1.25V at 0.2 A. These loads **120** may be grouped together into a load group **210** having a load requirement **215** of 1.25V at a combined current of 3.2 A. Load groups **210** may allow for the powering of multiple loads **120** by a single power supply component **205**, thus reducing in the total number of required power supply components **205** for a power supply architecture **305**. Further details regarding load groups **210** and load requirements **215** are discussed in detail below.

An intermediate rail voltage **220** may provide an intermediate voltage level between an input voltage source **115** and an output voltage to power a load **120** or load group **210**. The intermediate rail voltage **220** may be used as an input to a power supply component **205** configured to produce an output for one or more of the loads **120** or load groups **210**. An intermediate rail voltage **220** may be produced by way of a power supply component **205** configured to power the intermediate voltage level. Intermediate rail voltages **220** may require additional power supply components **205** to produce the intermediate rail voltages **220**. However, the use of intermediate rail voltages **220** may allow for the use of more efficient, lower power, or lower cost power supply components **205** to supply the loads **120**, where these power supply components **205** may not be usable or as efficient they were connected to the input voltage source **115** directly. Further details regarding intermediate rail voltages **220** are discussed in detail below.

The exemplary power supply design **125**A includes an LM5088 power supply component **205** (SUPPLY__1) configured to generate a 12V intermediate rail voltage **220** and also to power the eighth load **120**. The power supply design **125** further includes an LM3150 power supply component **205** (SUPPLY__2) configured to supply 1.25V to a load group **210** including the first and seventh loads **120** and drawing from the 12V intermediate rail voltage **220**. The power supply design **125** further includes an LM3153-3.3 power supply component **205** (SUPPLY__3) configured to supply 3.3V to a load group **210** including the second, third, fourth, and ninth loads **120**, also drawing from the 12V intermediate rail voltage **220**. The power supply design **125** further includes an LM22675-ADJ power supply component **205** (SUPPLY__4) configured to supply 1.8V to the fifth load **120**, also drawing from the 12V intermediate rail voltage **220**. The power supply design **125** further includes an LM22674-ADJ power supply component **205** (SUPPLY__5) configured to supply 2.5V to the sixth load **120**, also drawing from the 12V intermediate rail voltage **220**.

It should be noted that the power supply design **125** illustrated in FIG. **2** is merely exemplary, and other power supply designs **125** configured to power the same or different sets of loads **120** are possible. For example, one or more of the power supply components **205** providing power to the multiple loads **120** may be powered from the input voltage source **115** directly, without making use of any intermediate rail voltages **220**. As another example, more or fewer loads **120** may be powered by the intermediate rail voltages **220**. As yet a further example, an intermediate rail voltage **220** may power another intermediate rail voltages **220**, which in turn power one or more power supply components **205** providing power to one or more loads **120**. Accordingly, in some examples a load requirement **215** may be a requirement for a power supply component **205** to supply power to one or more intermediate rail voltages **220** as well as to one or more loads **120** or load groups **210**.

FIG. **2**B shows an example of a power supply design **125**B that includes a multi-channel voltage regulator. The input voltage source **115** in this example provides 32V at 1.7 A to power supply components SUPPLY__1 (e.g., a TPS54540), SUPPLY__2 (e.g., a TPS54540), SUPPLY__3 (e.g., a LM25011), and SUPPLY__4 (e.g., a LM20242). The loads in this example are the same as in FIG. **2**A. SUPPLY__1 is a single-channel voltage regulator that produces 1.25V at 3.2 A for loads LOAD__1, LOAD__7 and LOAD__4. LOAD__1 and LOAD__7 are grouped together in a load group **210**. SUPPLY__2 is also a single-channel voltage regulator that produces 3.3V at 4 A for powering LOAD__4 and LOAD__9 which are also grouped together as shown. SUPPLY__3 is a single-channel voltage regulator that produces 12V at 2 A for powering LOAD__8.

SUPPLY__4 is a single-channel voltage regulator that produces an intermediate voltage rail **220** (5V at 1.19 A). The intermediate voltage rail **220** is provided to SUPPLY__5 which is a multi-channel voltage regulator. (e.g., an LP3907). The multi-channel voltage regulator provides four channels (CH1-CH4). Channel 1 is configured to provide 1.8V at 1 A for power LOAD__5. Channel 2 is configured to provide 3.3V at 0.5 A for powering LOAD__2. Channel 3 is configured to provide 2.5V at 0.2 A for powering LOAD__6. Channel 4 is configured to provide 3.3V at 0.2 A for powering LOAD__3.

FIG. **3** illustrates five exemplary power supply architectures **305**-A through **305**-E that may be used to power the same set of loads **120** discussed above with respect to FIGS. **2**A and **2**B. The power supply architecture **305**-A illustrates an exemplary power supply design **125** from which a power supply designs **125** such as the one shown in FIG. **2**A may be constructed. Additionally, FIG. **3** further illustrates several additional power supply architectures **305**-B through **305**-E that may also be used to produce power supply designs **125** that power the multiple loads **120**. For example, power supply designs **125** may be created according to power supply architecture **305**-B having no intermediate rail voltage **220**, power supply architecture **305**-C having 3V, 5V, and 12V intermediate rail voltages **220**, and power supply architecture **305**-D having a 24V intermediate rail voltage **220**. The power supply architectures of **305**-A, **305**-B, **305**-C, and **305**-D include single-channel voltage regulators only. Power supply architecture **305**-E and **305**-F include a multi-channel voltage regulator. Power supply architecture **305**-E tracks the example of FIG. **2**B and **305**-E provides an alternative architecture but one that also includes a multi-channel voltage regulator.

FIG. **4** illustrates an exemplary modularization of the power supply design tool application **160**. As shown in the figure, the power supply design tool application **160** may include a user interface module **402**, requirements module **404**, an architecture determination module **406**, a component determination module **408**, a circuit design module **410**, a circuit optimization module **412**, a schematic determination module **414**, a board layout module **416**, an electrical simulation module **418**, a thermal simulation module **420**, a bill of materials module **422**, a best results determination module **424**, a tabular display module **426**, a graphical display module **428**, a design list filter module **430**, an optimization control module **432**, a component acquisition module **434**, an architecture navigation module **436**, and a report module **438**. Although only one example of the modularization of the power supply design tool application **160** is illustrated and described, it should be understood that the operations thereof may be provided by fewer, greater, or differently named modules.

As shown in FIG. **4**, the various modules comprising the power supply design tool application **160** are stored on a non-transitory computer-readable medium **161** and are executable by a processing resource **163**. The processing resources may include a single processor, multiple processors, a single computer (e.g., application server) or a network of computers. The non-transitory computer-readable medium **161** may include volatile storage (e.g., random access memory), non-volatile storage (e.g., hard drive, optical disk, flash storage, etc.) or combinations thereof.

The user interface module **402** may be configured to provide the user interface **110** to be displayed by way of the user device **105**. For example, the user interface module **402** may be implemented by way of one or more web pages configured to accept the design requirements **130** from a user and provide output to the user including power supply designs **125**. The user interface module **402** may be implemented using technologies such as Java, AJAX, Adobe Flex, Adobe Flash, Microsoft.NET, among others. The user interface module **402** may be configured to generate web pages via the application server **155** to be transmitted to the user device **105** via the communications network **135**. These web pages may then be viewed by the user on the user device **105** using a web browser program.

Exemplary user interfaces **110** allowing for the specification of design requirements **130** and the viewing of power supply designs **125** are illustrated with respect to FIGS. **6-10** described below. It should be noted that the while specific user interfaces **110** are illustrated in the exemplary figures, the particular user interfaces **110** presented by the power supply architecture design tool application **160** and the user interface module **402** may vary from implementation to implementation.

The requirements module **404** may be configured to utilize the user interface module **402** to allow the user of the user device **105** to specify design requirements **130** for the power supply designs **125**. For example, the requirements module **404** may cause the user interface module **402** to generate web pages configured for receiving the design requirements **130**.

The requirements module **404** may be configured to allow a user to specify design requirements **130** including one or more input voltage sources **115**. For example, a user may provide minimum, maximum, and nominal input voltage, ambient temperate, maximum input current and/or other critical design inputs about the input voltage source **115**. The user may add additional input voltage sources **115** to the design requirements **130** if desired.

The requirements module **404** may further be configured to allow a user to specify design requirements **130** including a set of loads **120** to be provided power by the power supply design **125**. For example, the user may provide voltage, current, name and other power supply attributes for multiple loads **120**. In some examples, the requirements module **404** may allow for the import or upload of data regarding a set of multiple loads **120** from an input file, such as a text file or spreadsheet. One or more loads **120** may be assigned to a specific input voltage source **115** by a user if desired, or the loads **120** may be automatically assigned to input voltage sources **115**.

The architecture determination module **406** may determine a variety of different power supply architectures **305** that may be appropriate to power the loads **120**, based on one or more design heuristics **165** of the system **100**. Based on the user-provided design requirements, at least one of the power supply architectures determined by the architecture determination module **406** includes at least one multi-channel voltage regulator. The architecture determination module **406** may selectively group various of the loads **120** into load groups **210**. Each load group shares a common supply. Further, the architecture determination module **406** may determine potential intermediate rail voltages **220**, define load requirements **215** for each of the load groups **210** and intermediate rail voltages **220**, and construct power supply architectures **305** based on at least a subset of the design requirements **130**, loads **120**, load groups **210**, load requirements **215**, and potential intermediate rail voltages **220**. Based on the groupings and arrangements, the architecture determination module **406** may define one or more positions into which power supply components **205** are to be included, as well as load requirements **215** for each of the positions. At least one of the positions for some of the determined architectures is occupied by a multi-channel voltage regulator as determined by the architecture determination module **406**.

In accordance with various embodiments, the architecture determination module **406** determines power supply architectures that only include single channel voltage regulators in parallel or sequentially with architectures that include multi-channel voltage regulators. The resulting combined architectures are then presented to the user for comparison and analysis.

To determine a power supply architecture that includes a multi-channel regulator, the architecture determination module **406** selects for consideration each multi-channel voltage regulator from the database. For each such multi-channel voltage regulator, the architecture determination module **406** scans all unassigned loads through the channels of that regulator to determine a channel utilization level. A load can be assigned to a particular channel of the multi-channel regulator if that particular channel can supply the appropriate combination of voltage and current for the given load. If more than a threshold amount (e.g., 50%) of the multi-channel voltage regulator's channels can be assigned user-specified loads, then that multi-channel voltage regulator is included in the power supply architecture. The threshold amount may be preset (e.g., 50% default) or may be user-specified through a graphical user interface (GUI). Loads are then assigned to the channels of the regulator until either all loads have been assigned, all channels are occupied with loads, or an empty channel remains but no more loads can be assigned to that channel (e.g., because that channel cannot supply the correct voltage/current for a remaining unassigned load).

Additional multi-channel voltage regulators are selected and analyzed in a similar fashion until either all loads are assigned or all multi-channel voltage regulators have been considered. At that point, if one or more loads remain as being unassigned to a voltage regulator, then single-channel voltage regulators are selected for the remaining such loads. This process is described in more detail below and in particular with regard to the flow charts of FIGS. **5**A-**5**D.

As explained above, part of the power supply architecture determination process may include combining loads of a common voltage requirement for powering by a common voltage regulator. Based on one or more design heuristics **165** of the system **100**, the architecture determination module **406** may selectively combine loads **120** specified by the design requirements **130** into load groups **210**, where the grouped loads **120** in the load group **210** may utilize a common power supply. As an example, one or more system **100** design heuristics **165** may specify for the architecture determination module **406** to group loads **120** with the same voltage together on a common power supply. The architecture determination module **406** may accordingly determine a load requirement **215** for each load group **210** by summing the current requirements for each of the loads **120** in the load group **210**. However, the design requirements **130** may specify that a load **120** requires a unique supply, in which case that load **120** would not be grouped with other loads **120** on a common supply.

To aid in the determination of whether to group loads **120** into load groups **210**, the one or more design heuristics **165** of the system **100** may specify a threshold current value above which it would be less likely to find a suitable power supply component **205** for a power supply design **125**. Accordingly, if a load group **210** results in a sum of the load **120** currents being above the threshold value, the architecture determination module **406** may break the loads **120** down into two or more load groups **210**, each with a smaller total current, to allow for a greater number of possible power supply components **205** to be available to provide power to the load groups **210**.

The architecture determination module **406** may accordingly determine load requirements **215** for each position in a power supply architecture **305** based at least in part on the summed currents for each load group **210**.

Based on one or more design heuristics **165**, the architecture determination module **406** may calculate one or more potential intermediate rail voltages **220**. Using the calculated intermediate rail voltages **220**, the architecture determination module **406** may generate various power supply architectures **305** having zero or more of the potential intermediate rail voltages **220**. For example, FIG. **3** discussed above illustrates an exemplary set of power supply architectures **305** capable of powering the same set of loads **120**, where each exemplary power architecture **305**-A through **305**-F has a different configuration of intermediate rail voltages **220** and some architectures include multi-channel voltage regulators, while other architectures do not. Accordingly, power supply architectures **305** including various intermediate rail voltages **220** and single or multi-channel voltage regulators may allow for the generation of power supply designs **125** having different characteristics and tradeoffs.

An example of a design heuristic **165** that may be utilized to calculate power supply architectures **305** having intermediate rail voltage **220** may be to calculate appropriate intermediate rail voltage **220** according to the duty cycle of downstream regulators, targeting low, medium, and high duty cycle for the downstream supplies.

Another example of a design heuristic **165** that may be used to calculate power supply architectures **305** having intermediate rail voltage **220** may be to set different percentages of the difference between the input voltage source **115** and the loads **120** or load groups **210**. Exemplary percentages for intermediate rail voltage **220** may include 75%, 50%, and/or 25% of the voltage difference between a voltage source and a load. For instance, if an input voltage source **115** is 50V, and one of the loads **120** requires a 10V supply (i.e., 40V difference), then possible power supply architectures **305** may include an intermediate rail voltage of 30V, 20V, or 10V (i.e., 75%, 50%, and 25% of the 40V difference between the 50V input voltage and the 10V load voltage).

Using the calculated intermediate rail voltage **220**, the architecture determination module **406** may generate various power supply architectures **305** by utilizing various combinations of the intermediate rail voltages **220**. Using one of the combinations of zero or more intermediate rail voltages **220**, the architecture determination module **406** may start at each load **120**, or load group **210**, and may sum up the currents or use the summed current from a corresponding load requirement **215**. Then for each load **120** or group of loads **120**, the architecture determination module **406** may determine to use the voltage of an intermediate rail voltage **220**, if it exists, whose voltage is above that of a particular load **120**. If no intermediate rail voltage **220** is present, then the architecture determination module **406** may utilize the input voltage source **115** as the input voltage for the supply for the load **120**. In some instances, architecture determination module **406** may further determine whether or not to use the voltage of an intermediate rail voltage **220** if it can support the total current required and/or if the total required current is below a threshold value. Thus, the architecture determination module **406** may determine a power supply architecture **305** for the combination of zero or more intermediate rail voltages **220**.

For each position in the determined power supply architecture **305**, the architecture determination module **406** may further determine a load requirement **215** (e.g., voltage and current) for power supply components **205** that may fill the position. For example, a load requirement **215** for a position may be to supply power to one or more loads **120**, while another load requirement **215** for a position may be to supply power to an intermediate rail voltage **220**. As yet another example, a load requirement **215** for a position may be to supply power to one or more intermediate rail voltages **220** as well as to one or more loads **120**.

The architecture determination module **406** may determine a plurality of potential power supply architectures **305** according to different combinations of input voltage sources **115** and intermediate rail voltages **220** with the loads **120** specified by the design requirements **130**. Each of the determined power supply architectures **305** may accordingly include one or more positions at which a power supply component **205** (such as a multi-channel voltage regulator) may be required. In some instances, a design heuristic **165** indicates a maximum number of power supply architectures **305** to be determined by the architecture determination module **406**.

Referring back to FIGS. **2**A and **2**B, there are five positions in which a power supply component **205** may be required. In the example of FIG. **2**A, four of the five positions provide power to loads **120** directly, and the other position provides an intermediate rail voltage **220**. Because the group of 1.25V volt supplies includes a load requiring 3 A and a load requiring 0.2 A, the power supply component **205** for the 1.25V position labeled "Supply 2" in FIG. **2**A has a load requirement of 1.25V at 3.2 A. Similarly, the group of 3.3V loads at the position labeled "Supply 3" has a load requirement of 3.3V at 4.7 A. Additional exemplary power supply architectures **305** are shown in FIG. **3** as well, including power supply architecture **305**-B with five positions in which a power supply component **205** may be required and no intermediate rail voltages **220**, and power supply architecture **305**-C having seven positions in which a power supply component **205** may be required and three intermediate rail voltages **220**. In the example of FIG. **2**B, four of the five positions (SUPPLY_1, SUPPLY_2, SUPPLY_3, and SUPPLY_5) provide power to loads **120** directly, while one position (SUPPLY_4) supplies power for an intermediate voltage rail **220** (which powers SUPPLY_5).

The component determination module **408** may be configured to determine one or more power supply components **205** that could be used to build circuits for a given power supply architecture **305**. For instance, for each of the potential power supply architectures **305** determined by the architecture determination module **406**, the component determination module **408** may determine power supply components **205** to provide power to one or more loads **120**, load groups **210**, and/or intermediate rail voltages **220**.

More specifically, the component determination module **408** may determine a power supply component **205** that could satisfy the load requirements **215** for a particular position by applying filters to component information **150** stored in data store **145**. The load requirements **215** may include output voltage and output current fields based on the grouped design requirements **130** for the loads **120**. The filters may compare values specified in the load requirements **215** against values in corresponding information in the component information **150**. The components selected may include, for example, single-channel voltage regulators and multi-channel voltage regulators.

As another example, the component determination module **408** may utilize values from the load requirements **215** as inputs to one or more design heuristics **165**, where the outputs of the one or more design heuristics **165** may be used to determine which power supply components **205** could potentially satisfy the load requirements **215** for a particular position. For instance, when designing a boost regulator circuit, a design heuristic **165** may be used to determine which power supply components **205** used in boost regulators may meet the switch current requirements implicit in the load requirements **215** for a particular position. Accordingly, to determine which power supply components **205** may be used in that position, the input voltage, output voltage and output current specified for the position may be used to calculate a required switch current rating, where the required switch current rating is compared against the switch current ratings in the component information **150** stored in data store **145** to select only those power supply components **205** that can satisfy the requirements for the position. As yet a further example, the component determination module **408** may filter components to include only components from preferred vendors, manufacturers, or suppliers.

Thus, for each position in the power supply architecture **305** in which a power supply components **205** would be required, a list of possible power supply components **205** for each position in the power supply architecture **305** may be determined. For example, as shown in FIG. **2**A, an LM3150 power supply component **205** may be used to meet the load requirements **215** for the position labeled "Supply 2," and an LM3153-3.3 power supply component **205** may be used to meet the load requirements **215** for the position labeled "Supply 3." In some examples, the component determination module **408** may further maintain a list of reasons for the exclusion of power supply components **205** that may be unsuitable for use in a particular position, so that a user may be informed why a particular power supply component **205** is not indicated as being available for use.

A circuit may contain many more supporting components in addition to a particular power supply component **205** that may be used to satisfy at least a subset of the design requirements **130**. Based on the determined power supply components **205**, the circuit design module **410** may be utilized to determine the supporting components, or parameters and bounds for the supporting components. The circuit design module **410** may further be configured to determine a circuit topology indicating how those additional supporting components may be arranged to create the circuit with the power supply components **205**.

The circuit design module **410** may utilize design heuristics **165** and including various rules and mathematical formulas to select adequate values for the additional components. For example, if the design requirements **130** indicate that a load **120** is to be provided a minimal output voltage ripple, a design heuristic **165** may indicate that a larger output capacitor value may be chosen as a supporting component. As another example, if the design requirements **130** indicate that a power supply may be required to withstand sudden change in input voltage (i.e., transient response) then a design heuristic **165** may indicate that a smaller output capacitor value may be chosen as a supporting component.

In some instances, rather than determining a particular value for a supporting component, the circuit design module **410** may instead utilize design heuristics **165** to determine a range of potential values for an additional component of the circuit. For example, for a certain design, an output capacitor must have a capacitance greater than or equal to 100 μF and an equivalent series resistance of less than or equal to 100 MΩ. These rules may then be used by the circuit design module **410** to select supporting components from the parts described in the component information **150** of the data store **145**.

The circuit optimization module **412** may be configured to aid in the determination of power supply components **205** and supporting components. For example, the circuit optimization module **412** may determine supporting components that satisfy the range of potential values determined by the circuit design module **410**, while also accounting for design preferences indicated in the design requirements **130** through use of optimization heuristics **170**. These optimizations and design preferences may accordingly guide the determination of some or even all of the components **205** and supporting components of the power supply designs **125**.

Parameters of a component part may be determined based on the component information **150** stored in the data store **145**. Accordingly, selection of component parts for a design may be based on an algorithm in which a target value is set for the parameters of the component part. The closer a component parameter is to a target value, the higher the score for that parameter. A weight may also be assigned to each parameter of a component. Thus, a final score for each component may be determined based on the initial score and the weight (e.g., determined as a product of the initial score and the weight). If two parameters with a same deviation from a target value have different weights, the one with a higher weight would receive a higher overall score. This weighted scoring algorithm allows selection of components taking into account multiple parameters at once, keeping a balance between important characteristic factors of the component part such as footprint, parasitic resistance, capacitance, and inductance.

As an example, a design requirement **130** may indicate a preference for power supply designs **125** having high efficiency or low voltage ripple. Accordingly, an optimization heuristic **170** may set a low target for an equivalent series resistance (ESR) parameter of an output capacitor to reduce power dissipation and/or ripple. An optimization heuristic **170** may further set a high weighting for the ESR parameter in relation to other parameters. Using these optimization heuristics **170**, capacitors with low ESR would typically achieve higher scores than capacitors with higher ESR, giving the resultant designs improved efficiency.

The optimization heuristics **170** may further allow consideration of other parameters, such as size, capacitance, price, vendor, supplier, manufacturer and part availability in order to determine an overall score for a component. As an example, design requirements **130** may indicate a preference for designs having high efficiency, low cost, and parts that are in stock. Accordingly, one or more optimization heuristics **170** may place a relatively higher weight on a part being in stock at a fulfillment warehouse, a relatively higher weight on a part having a low price, and a relatively higher weight on a part having a low ESR. In such an example, a capacitor having a low ESR, but being out of stock at the fulfillment warehouse and having a high price may receive a lower overall score than a part one that is in stock, less expensive, but with a higher ESR.

In some instances, one or more of the architecture determination module **406**, the component determination module **408**, the circuit design module **410**, and the circuit optimization module **412** may utilize a cutoff to generate up to a maximum number of power supply designs **125**. This cutoff may indicate a maximum total number of power supply designs **125** to include in the universe of possible solutions. In other instances, a cutoff may indicate a maximum number of power supply designs **125** per power supply architecture **305**.

The schematic determination module **414** may be configured to produce a schematic diagram including the particular power supply components **205** and supporting components determined by the component determination module **408**, circuit design module **410**, and circuit optimization module **412**. In some examples, the schematic determination module **414** may be configured to generate a schematic that may be displayed to a user in a user interface **110** on a web page, by way of the user interface module **402**.

For example, the schematic determination module **414** may be configured to draw an electrical schematic by way of the user interface module **402**, using vector-based drawing techniques within a web browser application executed by a user device **105**. The electrical schematic may show wires and components such as voltage regulator devices and capacitors. In some examples, the schematic determination module **414** may be configured to provide a scale adjustment to allow for a user to adjust the scale at while a schematic is drawn, and zoom in and out of the schematic.

The schematic determination module **414** may further be configured to draw feature blocks that represent collections of components in an included electrical schematic or sub-circuit, rather than drawing each individual component of a sub-circuit. For example, each position in a power supply architecture **305** into which a power supply component **205** is included may be represented as a feature block in the schematic, rather than as a full schematic indicating each supporting component of the power supply component **205**. As some further examples, a feature block may represent a sub-circuit configured to create an intermediate rail voltage **220**, a sub-circuit configured to provide a power output to a load **120** from an intermediate rail voltage **220**, or a sub-circuit configured to provide a power output to a load **120** from an input voltage source **115** directly.

In some instances, the schematic determination module **414** may be configured such that each sub-circuit configured to provide an intermediate rail voltage **220** and/or a power output for a load **120** may be represented as feature block in the electrical schematic. A schematic including such feature blocks would accordingly allow for a higher-level representation of the power supply design **125** to be displayed. The schematic determination module **414** may further be configured to display the corresponding sub-circuit for a feature block upon indication by the user. In some instances, it may be possible for a hierarchy to be created in which feature blocks include sub-circuits that in turn also have included feature blocks including their own sub-circuits.

The schematic determination module **414** may be configured to provide a level-of-detail adjustment to allow for a user to adjust the level of detail at while a schematic is drawn. For example, at a higher level of detail, some or all levels sub-circuits may be represented as their individual components, while at a lower level of detail, a greater number or level of sub-circuits may be represented as feature blocks.

The schematic determination module **414** may further be configured to allow for the selective editing of various components or wires of a schematic diagram, and the schematic determination module **414** may visually indicate which components and/or wires in the schematics may be modifiable. For example, components that are modifiable may be illustrated in color, while components that are non-modifiable may be presented in a black-and-white format. As another example, components that are modifiable may be presented accompanied by a particular graphic.

For components that are indicated as being editable, the schematic determination module **414** may allow for the user to substitute another component for the indicated component. Additionally, one or more ends of a wire included in the schematic may be capable of being moved by a user to allow for additional customization of the schematic.

The board layout module **416** may be configured to create a printed circuit board (PCB) layout according to a determined schematic, such as an electrical schematic determined by the schematic determination module **414**. The board layout module **416** may determine an appropriate PCB layout according to various parameters, including the topology the circuit, the IC selected, the size of the selected components, whether the design requires a large amount of copper to dissipate heat or a heat sink to dissipate heat, and the like.

In some examples, the board layout module **416** may be configured to receive an indication of a size of a board on which to layout the components. For instance, the board layout module **416** may provide controls, by way of user interface module **402**, to allow for user specification of one or more of PCB width, PCB height, and PCB mounting depth. In other examples, the board layout module **416** may automatically determine where the components are placed on a printed circuit board and delete the portions of the board not used by the components. Thus, the board layout module **416** may be configured to automatically crop the PCB layout based on the components used in the circuit.

In some examples, the board layout module **416** may be configured to determine a PCB layout according to a predetermined landing area approach. In such an approach, a PCB layout of the design is created with a mount for a particular integrated circuit (such as an LM2678 semiconductor) and also with landing pads for various supporting components to be used with the particular IC. The landing pads may be designed to accommodate a variety of combinations of supporting components, which vary in size and shape, by creating the landing pads for the supporting components large enough and spaced closely enough to accommodate different sizes of components that may potentially be used with the IC. Thus, a single PCB board may be used to accommodate many different schematics, having various sizes and varieties of surface mount components.

The electrical simulation module **418** may be configured to allow for an electrical simulation of an electrical schematic, allowing for a user to observe the performance of the circuit under simulated operating conditions. For example, the electrical simulation module **418** may be utilized to determine an electrical efficiency of a power supply design **125**.

The thermal simulation module **420** may be configured to identify heat problems on a PCB early on in the design process and correct the issues before a PCB goes into production. Early diagnosis of a thermal issue may save a time and avoid costly quality accidents. The thermal simulation module **420** may be configured to simulate the thermal behavior of an electronic PCB having various components. The thermal simulation module **420** may use thermal models for components to aid in the analysis. For PCBs that are laid out using a standard PCB layout, the thermal simulation module **420** may further utilize a thermal model for the standard PCB layout.

Based on the PCB and components, the thermal simulation module **420** may utilize a conduction, radiation and convection solver. For instance, the thermal simulation module **420** may utilize the WebTHERM module provided by Flomerics, Inc. to conduct the thermal simulations. The output of the thermal simulation may be illustrated graphically by way of the user interface module **402**, such as by a plot of the PCB under the design's steady state electrical load **120** conditions, illustrating an estimate of the generated heat.

The bill of materials module **422** may be configured to determine a bill of materials (BOM) including the list of parts used for each of the power supply designs **125**. The bill of materials module **422** may further determine a total cost of the design and a total number of components for the design. For example, the bill of materials module **422** may query the data store **145** for component information **150** related to pricing of the utilized components, and may determine an overall cost of the power supply design **125** based on a total sum of the cost of each utilized component.

In some examples, the bill of materials module **422** may be configured to prefer components from particular vendors, suppliers, manufacturers over other components. As one possibility, the bill of materials module **422** may list components only from a preferred vendor whenever possible.

The best results determination module **424** may be utilized to determine one or more best results from a set of power supply designs **125**. For instance, the best results determination module **424** may determine a ranking of the individual designs in the set of power supply designs **125**. The best results determination module **424** may determine the ordering and recommended designs by using a weighted scoring system. As an example, a design requirement **130** may indicate a preference for power supply designs **125** having high efficiency. Accordingly, based on the design requirement **130**, the best results determination module **424** may rank the power supply designs **125** according to electrical efficiency for the overall power supply designs **125**, where the overall efficiencies may be determined by the electrical simulation module **418**.

The best results determination module **424** may determine the ordering while accounting for multiple variables simultaneously. Similar to as discussed above with regard to component selection, the best results ordering may use an algorithm in which a target value is set for one or more parameters of a power supply design **125**. The closer a parameter of the power supply design **125** is to the corresponding target, the higher the score for that parameter. A weight may also be assigned to each parameter. Thus, a final score for each power supply design **125** may be determined based on the initial score and the weight (e.g., as a product of the score and weight values). For example, if two parameters with a same deviation from a target value have different weights, the one with the higher weight would receive a higher overall score. This weighted scoring algorithm allows ordering of power supply designs **125** taking into account multiple parameters at once, keeping a balance between important characteristic factors of the component part such as footprint, parasitic resistance, capacitance, and inductance.

The best results determination module **424** may utilize a cutoff to provide up to a maximum number of power supply designs **125**. In some instances, a cutoff may indicate a maximum total number of power supply designs **125** to include in the universe of possible solutions. In other instances, a cutoff may indicate a maximum number of power supply designs **125** per power supply architecture **305**.

The best results determination module **424** may indicate the power supply design **125** having the best ranking as being the recommended design. Further, the power supply design **125** out of a set of power supply designs **125** for one particular power supply architecture **305** may be indicated as being the recommended design for that power supply architecture **305**.

The tabular display module **426** may be configured to display a list of the determined power supply designs **125** by way of the user interface module **402**. For example, the tabular display module **426** may present a use interface including a table of power supply designs **125** with key parameters displayed, with each row in the table indicating a particular power supply design **125** and associated values and key parameters. Key parameters may include system footprint determined by the board layout module **416**, system BOM cost and system component count determined by the bill of materials module **422**, system efficiency determined by the electrical simulation module **418**, among others.

The values in the table may be arranged according to the ranking determined by the best results determination module **424**. For examples, values in the table may be arranged with the best recommendations at the top of a sortable list. As an example, a design requirement **130** may indicate a preference for designs having high efficiency. Accordingly, based on ranking determined by the best results determination module **424**, the power supply designs **125** may be displayed in order according to electrical efficiency.

The graphical display module **428** may be configured to provide a graph of the determined power supply designs **125** by way of the user interface module **402**. The graphical display module **428** may represent the tradeoffs between the various power supply designs **125** by representing various key parameters as the X and Y axes of the graph. The graphical display module **428** may further represent the points within the graph as items of varying size and/or color to indicate a third key parameter as a third dimension. Thus, the graph can contain more than two dimensions by using circles of different diameters for each data point to signify larger or smaller values and/or different colors to represent differences in the values being plotted.

As an example, the axes may default to system footprint and system efficiency, with a circle around each data point of variable size to represent the BOM cost. The size of the circle may accordingly vary in size to become larger for a higher BOM cost and smaller for a lower BOM cost. The graphical display module **428** may be configured to allow a user to configure the axes of the graph, allowing the user to visualize other parameters in the design such as the V_{out} peak to peak ripple, frequency, and BOM count, among others.

The design list filter module **430** may be configured to allow for the filtering of the determined power supply designs **125** displayed by the tabular display module **426** and graphical display module **428**. For example, the design list filter module **430** may provide slider controls, check boxes and other controls by way of the user interface module **402** that may be used to specify filter criteria for the displayed power supply designs **125**. These controls may allow a user of the user device **105** to narrow down the list of power supply designs **125** according to the specified filter criteria. Because the filtering is performed based on the determined set of power supply designs **125** that form the universe of possible solutions, filtering of the power supply designs **125** may be performed by the user device **105** without requiring any additional database access or interaction with the data store **145**.

Exemplary filter criteria may include minimum and maximum efficiency, minimum and maximum footprint, minimum and maximum BOM cost, minimum and maximum BOM count, minimum and maximum ripple, minimum and maximum switching frequency, minimum and maximum crossover frequency, and minimum and maximum phase angle. Further exemplary filter criteria may include additional features that may be present on a utilized power supply component **205** package, such as: on/off pin, error pin, soft start, external synchronization, module, adjustable primary leakage inductance limit, adjustable frequency, synchronized switching, controller, and integrated switch. Still further filter criteria may include component vendor, supplier or manufacturer.

The optimization control module **432** may be configured to allow a user to specify system level goals such as small footprint, low cost, or high efficiency. The optimization control module **432** may utilize the user interface module **402** to present a control, such as a knob, to a user device **105**, and may receive input from the user from the control. The control may allow the user to select a tradeoff indicating a preference for at least one key parameter over a preference for at least one other key parameter. For example, the control may allow the user to prefer designs with small footprint over designs with high efficiency.

In some instances, based on the input from the control, the optimization control module **432** may be configured to cause the power supply design tool application **160** to calculate additional power supply designs **125** containing power supplies optimized according to the new system level goals indicated by the user. These additional power supply designs **125** may then be added to power supply designs **125**.

In other instances, the power supply design tool application **160** may be configured to pre-calculate power supply designs **125** optimized according to each of the potential system level goals or sets of optimizations settings that may be indicated by the user. Then, based on the input from the control, the optimization control module **432** may be configured to cause the power supply design tool application **160** to filter the displayed power supply designs **125** according to the particular optimization settings chosen by the user by way of the optimization control module **432**. By performing the filtering based on the pre-calculated power supply designs **125** optimized according to various optimizations settings, the filtering may be performed by the user device **105** without requiring any additional database access or interaction with the data store **145**.

An exemplary optimization control module **432** may present a knob providing for selection of one of the following sets of optimizations to use as the system design goals: a first optimization with the goals of smallest possible footprint accomplished through use of the highest possible switching frequencies; a second optimization with the goals of lowest possible cost with frequency pushed higher for smaller components; a third optimization with the goals of a balance of efficiency, footprint, low complexity, and cost; a fourth optimization with the goals of lowest possible cost with frequency pushed lower for increased efficiency; and a fifth optimization with the goals of highest possible efficiency, largest components.

The component acquisition module **434** may be configured to allow a user to purchase the list of parts used in a selected power supply design **125**. Using the BOM for a power supply design **125**, the component acquisition module **434** may be configured to confirm whether the parts are in stock by querying the component information **150** stored in data store **145**. If the parts are determined to be in stock, the component acquisition module **434** may allow the user to purchase a set of parts for building all or a portion of the power supply design **125**. The component acquisition module **434** may further be configured to provide assembly instructions for the board that shows the locations of all the components, soldering instructions, an electrical schematic, top-side and bottom-side copper layout diagrams, instructions for building and testing the circuit. In some examples, the component acquisition module **434** may provide an option for the user to receive an assembled version of the power supply design **125**. In some examples, the component acquisition module **434** may prefer to order components from preferred vendors, suppliers or manufacturers.

The architecture navigation module **436** may be configured to allow for navigation of the electrical schematic, such as the schematic determined by the schematic determination module **414**. Upon selection of one of the power supply designs **125**, such as through use of the tabular display module **426** and the graphical display module **428**, the architecture navigation module **436** may be configured to display, by way of the user interface module **402**, a user interface **110** including a feature block diagram illustrating the power supply architecture **305** of the selected design. For example, the schematic determination module **414** may determine an electrical schematic where each position in power supply design **125** into which a power supply component **205** and supporting components are included is represented as a feature block.

Further, the architecture navigation module **436** may be configured to receive selections of the feature blocks in the diagram, and display particular attributes for the selected feature block. The architecture navigation module **436** may further be configured to display charts and graphs depicting the relative contribution of each power supply component **205** to the power supply design **125** according to various key parameters, such as power dissipation, BOM cost, footprint, and component count.

The report module **438** may be configured to create a report summarizing the attributes of one or more designs. For example, the report module **438** may be utilized by a user to view a report summarizing the attributes of a selected design from the set of power supply designs **125**. The report may include system level attributes such as a feature block diagram, system efficiency, system BOM cost, and system component cost. The report may further include specific information about the input voltage sources **115** including the input voltage range. In addition, the report may include information about each specific power supply from the set of power supply designs **125**, including the corresponding schematic, BOM, and associated component information including electrical characteristics such as inductance, DC resistance, current rating, voltage rating, etc. Other information about each power supply may be included as well, such as operating values including duty cycle, efficiency, BOM cost, BOM footprint, currents through components, and power dissipation for components. The operating values may be included in a table or as plots of the operating value vs. other facts such as load **120** current for different voltages. The report may also contain simulation results, such as from the electrical simulation module **418** and/or thermal simulation module **420**, which may be represented in numeric form, tabular form such as via tabular display module **426**, and/or graphical form such as via graphical display module **428**. Reports generated by the report module **438** may be provided in various formats, such as the portable document format (PDF).

FIGS. **5A-5D** illustrate an exemplary process flow for determining a power supply for multiple loads **210**. The process flow may be performed by various systems, such as by the system **100** described above with respect to FIG. **1**. The disclosed process flow generates solutions with only single-channel voltage regulators as well as solutions with multi-channel voltage regulators.

In block **502**, a power supply design tool application **160** receives design requirements **130** from a user device **105**. For example, a communications network **135** may be in selective communication with a user device **105** and an application site **140**. The application site **140** may serve as a hosting platform for an application server **155** running the power supply design tool application **160**. A user interface module **402** and a requirements module **404** of the power supply design tool application **160** may be configured to provide a user interface **110** to a user device **105**, such as a web page, where the user interface **110** may allow the user of the user device **105** to specify the design requirements **130** for a power supply design **125**. The design requirements **130** may include information regarding a set of multiple loads **120** to be powered by one or more input voltage sources **115**, and whether the user desires for the design tool to generate solutions based on multi-channel voltage regulators.

In blocks **504** and **506**, the process flow generates single channel voltage regulator only solutions and multi-channel voltage regulator solutions, respectively. FIG. **5**B provides detail regarding block **504** and FIGS. **5**C and **5**D provide detail regarding block **506**.

After the various power supply design solutions are generated, in block **508**, the power supply design tool application **160** ranks the determined power supply designs **125** based on the design goals indicated in the design requirements **130**. For example, the power supply design tool application **160** may utilize a best results determination module **424** to determine one or more best results from a set of power supply designs **125**. The best results determination module **424** may determine a ranking of the individual designs in the set of power supply designs **125**. The best results determination module **424** may further determine an overall best design, and/or one or more recommended designs. Additionally, for each of the determined power supply architectures **305**, the best results determination module **424** may determine the best design out of the power supply designs **125** for each power supply architecture **305**.

In block **510**, the power supply design tool application **160** presents the power supply designs **125** to the user. For example, the power supply design tool application **160** may send the power supply designs to the user device **105** that form the universe of possible solutions for the design requirements **130**. The user device **105** may utilize a tabular display module **426** to display a table of the power supply designs **125** and key parameters, with each row in the table indicating a particular power supply design **125** and associated values. The power supply design tool application **160** may also utilize a graphical display module **428** to provide a graph of the determined power supply designs **125** representing tradeoffs between the various power supply designs **125** according to key parameters. In some examples, the power supply design tool application **160** presents only the best power supply design **125** for each determined power supply architecture **305**. The power supply design tool application **160** may further indicate which power supply design **125** out of the presented power supply designs **125** is determined to be the best design. Because the universe of possible power supply designs **125** has already been computed by the power supply design tool application **160**, the user device **105** may perform filtering of the determined power supply designs **125** displayed by the tabular display module **426** and graphical display module **428** without additional access or interaction with the data store **145**. After block **580**, the process **500** ends.

Turning now to FIG. **5**B (process flow for the generation of solutions with single channel (not multi-channel voltage regulators)), in block **514**, the power supply design tool application **160** groups the set of multiple loads **120** into one or more load groups **210** having corresponding load requirements **215**. For example, based on the loads **120** specified by the design requirements **130**, the power supply architecture design tool application **160** may utilize an architecture determination module **406** to selectively group loads **120** sharing a common voltage into load groups **210**.

In some instances, the design requirements **130** may specify that a load **120** requires a unique supply, in which case that load **120** would not be grouped with other loads **120** into a load group **210**. Additionally, the one or more design heuristics **165** of the system **100** may specify a threshold current value above which it would be less likely to find a suitable power supply component **205** for a power supply design **125**. Accordingly, if a load group **210** results in a sum of the load **120** currents being above the threshold value, the architecture determination module **406** may break the loads **120** down into two or more load groups **210**, each with a smaller total current, to allow for a greater number of possible power supply components **205** to be available to provide power to the load groups **210**.

The power supply architecture design tool application **160** may determine a load requirement **215** for a load group **210** according to the common voltage of the load group **210** and a sum of the currents of each load **120** of the load group **210**.

In block **516**, the power supply design tool application **160** determines intermediate rail voltages **220**. For example, the power supply architecture design tool application **160** may determine one or more potential intermediate rail voltages **220** according to one or more design heuristics **165**. An example of a design heuristics **165** that may be utilized by the power supply design tool application **160** to calculate intermediate rail voltage **220** may be to determine potential intermediate rail voltages **220** according to the duty cycle of downstream regulators, targeting low, medium, and high duty cycle for the downstream supplies. Another example of a design heuristic **165** that may be utilized by the power supply architecture design tool application **160** to calculate intermediate rail voltage **220** may be to determine potential intermediate rail voltages **220** according different percentages of the difference between the input voltage source **115** and the loads **120** or load requirements **215**.

In block **518**, the power supply design tool application **160** determines power supply architectures **305** that may be used to satisfy the received design requirements **130**. The architecture determination module **406** may generate various power supply architectures **305** by utilizing various combinations of the intermediate rail voltages **220**. Using one of the combinations of zero or more intermediate rail voltages **220**, the architecture determination module **406** may start at each load **120**, or load group **210**, and may sum up the currents or use the summed current from a corresponding load requirement **215**. Then for each load **120** or group of loads **120**, the architecture determination module **406** may determine to use the voltage of an intermediate rail voltage **220**, if it exists, whose voltage is above that of a particular load **120**. If no intermediate rail voltage **220** is present, then the architecture determination module **406** may utilize the input voltage source **115** as the input voltage for the supply for the load **120**. In some instances, architecture determination module **406** may further determine whether or not to use the voltage of an intermediate rail voltage **220** if it can support the total current required and/or if the total required current is below a threshold value. Thus, the architecture determination module **406** may determine a power supply architecture **305** for the combination of zero or more intermediate rail voltages **220**. For each position in the determined power supply architecture **305**, the architecture determination module **406** may further determine a load requirement **215** (e.g., voltage and current) for power supply components **205** that may fill the position.

The architecture determination module **406** may determine a plurality of potential power supply architectures **305** according to different combinations of input voltage sources **115** and intermediate rail voltages **220** with the loads **120** specified by the design requirements **130**. FIG. **3** illustrates an exemplary plurality of potential power supply architectures **305** for a set of load requirement **215**. Each of the determined power supply architectures **305** may accordingly include one or more positions at which a power supply component **205** may be required. In some instances, a design heuristic **165** indicates a maximum number of power supply architectures **305** to be determined by the architecture determination module **406**.

In block **520**, the power supply design tool application **160** generates power supply designs **125** for the determined power supply architectures **305**. For example, the power supply design tool application **160** may utilize a component determination module **408**, a circuit design module **410**, and a circuit optimization module **412** to determine one or more power supply components **205** and supporting components that could be used to build circuits for a given power architecture **305**, optimized according to the design goals indicated in the design requirements **130**.

For each of the potential power supply architectures **305** determined by the architecture determination module **406**, the component determination module **408** may determine power supply components **205** to provide power to one or more loads **120**, load groups **210**, and/or intermediate rail voltages **220**. The circuit design module **410** may utilize design heuristics **165** and including various rules and mathematical formulas to select adequate values for the additional components. For example, the circuit optimization module **412** may determine supporting components that satisfy the range of potential values determined by the circuit design module **410**, while also accounting for design preferences indicated in the design requirements **130** through use of optimization heuristics **170**. These optimizations and design preferences may accordingly guide the determination of some or even all of the components **205** and supporting components of the power supply designs **125**.

In block **522**, the power supply design tool application **160** performs analysis of key parameters of the determined power supply designs **125**. For example, the power supply design tool application **160** may utilize a schematic determination module **414** to produce an electrical schematic diagram, and a board layout module **416** to create a PCB layout according to the determined schematic. The power supply design tool application **160** may utilize an electrical simulation module **418** to determine an electrical efficiency of an electrical schematic, and a thermal simulation module **420** to simulate the thermal behavior of the PCB layout. The power supply design tool application **160** may also utilize a bill of materials module **422** to determine a BOM including the list of parts used and the total part count for each of the power supply designs **125**.

FIGS. **5**C and **5**D provide a process flow example for the generation of power supply solutions that include at least one multi-channel voltage regulator. At **530**, the power supply design tool application **160** selects a multi-channel voltage regulator from a library of such parts in a database. Blocks **532**-**544** are then performed using the selected multi-channel voltage regulator. At **532**, the power supply design tool application **160** determines whether the selected multi-channel voltage regulator is compatible with the input voltage from source **115**. That is, a determination is made as to whether the selected multi-channel voltage regulator can operate correctly when provided with the input voltage from source **115**. If the multi-channel voltage regulator is not compatible with the input voltage, then at **534**, an intermediate voltage rail is added to the circuit on the front end of the multi-channel voltage regulator.

At block **536**, all unassigned loads are scanned through each channel of the selected multi-channel voltage regulator and a channel utilization level is calculated. During this scanning process, each load is evaluated against each channel of the multi-channel regulator. Each channel is capable of supplying a certain voltage (or voltage range) at a certain current (or current range). If the voltage and current needs of the load are within the capabilities of a particular channel, then the load can be assigned to that channel. A given load may be assignable to none or one or more of the channels of the regulator. The channel utilization level is the percentage of the regulator's channels that can be loads from among the loads not already assigned to a regulator.

If, as determined at block **538**, less than half of the regulator's channels are usable for the loads specified by the user, then control loops to block **546** at which it is decided if an additional multi-channel voltage regulator exists in the library for consideration. If a multi-channel voltage regulator exists in the library for consideration, the next multi-channel voltage regulator is selected at **530** and the process repeats for the newly selected regulator.

If, as determined at block **538**, more than half of the regulator's channels are usable for the loads specified by the user, then at **540**, the unassigned loads that can be assigned to the regulator are assigned a score based on the number of available channels of the regulator to which the load can be assigned. For example, if a load is assignable to only one channel of regulator, then that load may be assigned a score of 1. If another load is assignable to 3 channels of the regulator, then that load may be assigned a score of 3.

At **542**, the loads are assigned to channels of the multi-channel voltage regulator based on the loads' scores. For example, loads may be assigned starting with the load having the lowest score and continuing until no more loads remain to be assigned or until no more loads can be assigned (e.g., based on voltage/current incompatibility).

At block **544**, the power supply design tool application **160** determines whether any loads remain that have not yet been assigned to a channel of a multi-channel voltage regulator. If such loads are present, then control loops to decision block **546** for consideration as to whether an additional multi-channel voltage regulator exists in the library yet to be evaluated per the process flow of FIG. **5**C.

When all multi-channel voltage regulators have been evaluated and still at least one load remains yet to be assigned to a channel of a multi-channel voltage regulator, then control passes to block **548** at which the power supply design tool application **160** generates a power supply design **125** based on the multi-channel voltage regulator(s) to which loads have been assigned. At **550**, the power supply design tool application **160** performs analysis of key parameters of the determined power supply design **125**. For example and as described above, the power supply design tool application **160** may utilize a schematic determination module **414** to produce an electrical schematic diagram, and a board layout module **416** to create a PCB layout according to the determined schematic. The power supply design tool application **160** may utilize an electrical simulation module **418** to determine an electrical efficiency of an electrical schematic, and a thermal simulation module **420** to simulate the thermal behavior of the PCB layout. The power supply design tool application **160** may also utilize a bill of materials module **422** to determine a BOM including the list of parts used and the total part count for each of the power supply designs **125**.

Continuing with FIG. **5**D, the power supply design tool application **160** begins to assign the loads that could not be assigned to channels of the multi-channel voltage regulator(s) to single channel voltage regulators. This process is shown in FIG. **5**D and is similar to the process flow of FIG. **5**B in which single channel voltage regulators are selected.

At **552**, the power supply design tool application **160** groups the set of multiple unassigned loads **120** into one or more load groups **210** having corresponding load requirements **215**. For example, based on the loads **120** specified by the design requirements **130**, the power supply architecture design tool application **160** may utilize an architecture determination module **406** to selectively group loads **120** sharing a common voltage into load groups **210**.

As noted above, in some instances, the design requirements **130** may specify that a load **120** requires a unique supply, in which case that load **120** would not be grouped with other loads **120** into a load group **210**. Additionally, the one or more design heuristics **165** of the system **100** may specify a threshold current value above which it would be less likely to find a suitable power supply component **205** for a power supply design **125**. Accordingly, if a load group **210** results in a sum of the load **120** currents being above the threshold value, the architecture determination module **406** may break the loads **120** down into two or more load groups **210**, each with a smaller total current, to allow for a greater number of possible power supply components **205** to be available to provide power to the load groups **210**.

The power supply architecture design tool application **160** may determine a load requirement **215** for a load group **210** according to the common voltage of the load group **210** and a sum of the currents of each load **120** of the load group **210**.

In block **554**, the power supply design tool application **160** determines intermediate rail voltages **220**. For example, the power supply architecture design tool application **160** may determine one or more potential intermediate rail voltages **220** according to one or more design heuristics **165**. An example of a design heuristics **165** that may be utilized by the power supply design tool application **160** to calculate intermediate rail voltage **220** may be to determine potential intermediate rail voltages **220** according to the duty cycle of downstream regulators, targeting low, medium, and high duty cycle for the downstream supplies. Another example of a design heuristic **165** that may be utilized by the power supply architecture design tool application **160** to calculate intermediate rail voltage **220** may be to determine potential intermediate rail voltages **220** according different percentages of the difference between the input voltage source **115** and the loads **120** or load requirements **215**.

In block **556**, the power supply design tool application **160** determines power supply architectures **305** that may be used to satisfy the received design requirements **130**. The architecture determination module **406** may generate various power supply architectures **305** by utilizing various combinations of the intermediate rail voltages **220**. Using one of the combinations of zero or more intermediate rail voltages **220**, the architecture determination module **406** may start at each load **120**, or load group **210**, and may sum up the currents or use the summed current from a corresponding load requirement **215**. Then for each load **120** or group of loads **120**, the architecture determination module **406** may determine to use the voltage of an intermediate rail voltage **220**, if it exists, whose voltage is above that of a particular load **120**. If no intermediate rail voltage **220** is present, then the architecture determination module **406** may utilize the input voltage source **115** as the input voltage for the supply for the load **120**. In some instances, architecture determination module **406** may further determine whether or not to use the voltage of an intermediate rail voltage **220** if it can support the total current required and/or if the total required current is below a threshold value. Thus, the architecture determination module **406** may determine a power supply architecture **305** for the combination of zero or more intermediate rail voltages **220**. For each position in the determined power supply architecture **305**, the architecture determination module **406** may further determine a load requirement **215** (e.g., voltage and current) for power supply components **205** that may fill the position.

The architecture determination module **406** may determine a plurality of potential power supply architectures **305** according to different combinations of input voltage sources **115** and intermediate rail voltages **220** with the loads **120** specified by the design requirements **130**. FIG. **3** illustrates an exemplary plurality of potential power supply architectures **305** for a set of load requirement **215**. Each of the determined power supply architectures **305** may accordingly include one or more positions at which a power supply component **205** may be required. In some instances, a design heuristic **165** indicates a maximum number of power supply architectures **305** to be determined by the architecture determination module **406**.

In block **558**, the power supply design tool application **160** generates power supply designs **125** for the determined power supply architectures **305**. For example, the power supply design tool application **160** may utilize a component determination module **408**, a circuit design module **410**, and a circuit optimization module **412** to determine one or more power supply components **205** and supporting components that could be used to build circuits for a given power architecture **305**, optimized according to the design goals indicated in the design requirements **130**.

For each of the potential power supply architectures **305** determined by the architecture determination module **406**, the component determination module **408** may determine power supply components **205** to provide power to one or more loads **120**, load groups **210**, and/or intermediate rail voltages **220**. The circuit design module **410** may utilize design heuristics **165** and including various rules and mathematical formulas to select adequate values for the additional components. For example, the circuit optimization module **412** may determine supporting components that satisfy the range of potential values determined by the circuit design module **410**, while also accounting for design preferences indicated in the design requirements **130** through use of optimization heuristics **170**. These optimizations and design preferences may accordingly guide the determination of some or even all of the components **205** and supporting components of the power supply designs **125**.

In block **560** and as described above, the power supply design tool application **160** performs analysis of key parameters of the determined power supply designs **125** that include the single channel voltage regulators.

The process flow illustrated in FIGS. **5**C and **5**D begun with the selection of a multi-channel voltage regulator from a library containing multiple multi-channel voltage regulators. Additional multi-channel voltage regulators from the library are analyzed in sequence until as many loads as possible are assigned to channels of the various multi-channel voltage regulators. The process flow of FIGS. **5**C and **5**D is repeated additional times, each time starting with a different multi-channel voltage regulator from the library. For example, if the library contains 10 multi-channel voltage regulators, then the process flow of FIGS. **5**C and **5**D is repeated 10 times and may result in 10 different power supply designs depending, for example, on the multichannel regulator channel utilization.

FIG. **6** illustrates an exemplary user interface **110**-A for the input of design requirements **130**. For example, the user interface **110**-A may be generated by a user interface module **402** of a power supply design tool application **160**, and may allow for a user of a user device **105** to input design requirements **130**. As shown, the user interface **110**-A may provide for the input of one or more input voltage sources **115**, and a plurality of loads **120** assigned to the corresponding input voltage sources **115** by way of an add source control **605**, an add load control **610**, and a submit project requirements control **615**.

The user may utilize an add source control **605** to add an input voltage source **115** to the design requirements **130**. Each input voltage source **115** added to the design requirements **130** may allow for the specification of a name, an ambient temperature, a minimum voltage, and a maximum voltage.

The user may further utilize an add load control **610** to add an additional load **120** to the design requirement **130**. Each load **120** added to the design requirements **130** may allow for the specification of a name, a voltage for the load **120**, a maximum current for the load **120**, an optional percentage maximum for voltage ripple, optional filtration, an indication that a particular load **120** requires a separate supply for use in grouping the loads **120**, and a number of milliseconds of soft start time.

A user control **617** permits the user to specify whether the power supply design tool application is to generate solutions that include multi-channel voltage regulators. If the user selects that option, the process flow of FIGS. **5**A-**5**D is performed. If the user does not select this option, then the blocks **506** and all of FIGS. **5**C and **5**D are not performed, but the remaining blocks are performed.

Once the user has completed specification of the design requirements **130**, the user may select the submit project requirements control **615**. Upon selection of the submit project requirements control **615**, the power supply design tool application **160** may determine a set of generated power supply designs **125** according to the design requirements **130**.

FIG. **7** illustrates an exemplary user interface **110**-B for the input of design requirements **130**, illustrating the inclusion of multiple loads **120** into the design requirements **130**. As shown in user interface **110**-B, the set of loads **120** from user interface **110**-C are added to the design requirements **130**. If additional loads **120** or input voltage sources **115** are required, then the user interface **110**-B may allow for their inclusion by way of an add source control **605** and/or an add load control **610** as discussed about with respect to user interface **110**-A in FIG. **6**. Once the user has completed specification of the design requirements **130**, the user may select the submit project requirements control **615**.

FIG. **8** illustrates an exemplary user interface **110**-C illustrating a set of generated power supply designs **125**. As shown in the user interface **110**-C, five power supply designs **125** are included in a tabular list **805** and a graphical display **810** of the power supply designs **125**. The tabular list **805** may be created by a tabular display module **426** of the power supply design tool application **160**, and the graphical display **810** may be created by a graphical display module **428** of the power supply design tool application **160**. The user interface **110**-C further includes a schematic diagram **815** that may be created by a schematic determination module **414** illustrating a selected power supply design **125**.

Notably, rather than displaying fifty or more power supply designs **125** for each of the determined power supply architectures **305**, the tabular list **805** instead may display a best design for each of the different determined power supply architectures **305**. For example, the exemplary tabular list **805** as shown includes a best design for power supply architectures **305** having a 12V intermediate rail voltage **220**, a best design for power supply architectures **305** having both 5V and 12V intermediate rail voltages **220**, a best design for power supply architectures **305** having a 5V intermediate rail voltage **220**, a best design for power supply architectures **305** having a 23V intermediate rail voltage **220**, and a best design for power supply architectures **305** having no intermediate rail voltages **220**. The tabular list **805** may further include values for key parameters of the power supply designs **125** such as efficiency, footprint, BOM cost, and BOM count.

The displayed list of designs in tabular list **805** also includes multi-channel voltage regulator-based designs designated with the acronym PMU which stands for Power Management Unit. For example, design IDs **303-306** are PMU designs which include multi-channel regulators. Design IDs **300** and **301** do not include multi-channel voltage regulators.

The schematic diagram **815** represents on such multi-channel voltage regulator based design (ID **304**). The four channels of the multi-channel voltage regulator are illustrated in dashed box form.

These details of the power supply designs **125** may further be displayed graphically in the graphical display **810**. For example, in the graphical display **810** the X-axis may represent system efficiency, and the Y-axis may represent system footprint. The circle size in the graphical display **810** may indicate system BOM cost, where a larger circle represents a larger cost, and a smaller circle represents a smaller cost. The axis and the circles may be reconfigured to display different key parameters as well. For example, any of the X-axis, the Y-axis, and the circle size may be reconfigured to represent any of total efficiency, power dissipation, total footprint, total bill of materials cost, total component count, among others key parameters.

Further details of a selected one of the power supply designs **125** may also be illustrated in the user interface **110**-C, including by way of the schematic diagram **815** of the selected power supply design **125** that may be created by a schematic determination module **414**, as well as other key parameters of the selected power supply design **125**, such as the intermediate rail voltages **220**, total efficiency, power dissipation, total footprint, total bill of materials cost, total component count, and an optimization factor relating to the optimizations used to determine the selected power supply design **125**.

FIG. **9** illustrates an exemplary user interface **110**-D illustrating additional generated power supply designs **125**. These additional power supply designs **125** may be added by submitting additional design requirements **130** configured to optimize the power supply designs **125** for different values of key parameters. For example, additional power supply designs **125** may be generated upon selection of a different optimization setting from an optimization tuning dial **905** provided by an optimization control module **432** of the power supply architecture design tool application **160**. As shown in user interface **110**-D, the additional power supply designs **125** may be added to the tabular list **805** and graphical display **810**. Notably, the existing recommended designs optimized for previous design requirements **130** are retained in the displayed power supply designs **125**. This allows for the comparison of the best power supply designs **125** optimized according to different optimization settings.

It should be noted that in other examples, the power supply design tool application **160** may be configured to pre-calculate power supply designs **125** optimized according to each of the potential system level goals or sets of optimizations settings indicated by the user. Then, based on the input from the control, the optimization control module **432** may be configured to cause the power supply design tool application **160** to filter the displayed power supply designs **125** according to the particular optimization settings chosen by the user by way of the optimization control module **432**.

The user interface **110**-D may also allow for the filtering of the set of power supply designs **125** illustrated in the tabular list **805** and graphical display **810** by way of filtering controls **910**. The filtering may be performed by a design list filter module **430** of the power supply design tool application **160**, and may allow for filtering of the power supply designs **125** by the user device **105** according to parameters such as minimum and maximum efficiency, minimum and maximum footprint, minimum and maximum BOM cost, and minimum and maximum BOM count. Because the filtering is performed based on the determined set of power supply designs **125** that form the universe of possible solutions, filtering of the power supply designs **125** may be performed by the user device **105** without requiring any additional database access or interaction with the data store **145**.

Further details of a selected power supply design **125** may be illustrated upon selection of a project details control **915** of the user interface **110**-D.

FIG. **10** illustrates an exemplary user interface **110**-E illustrating such further details for one of the power supply designs **125**, including project charts **1005** related to key parameters of the one power supply design **125**. As shown in user interface **110**-E, the power supply design tool application **160** may include a schematic diagram **815** of the selected power supply design **125**, project charts **1005** relating to the selected power supply design **125**, and solution information **1010** relating to the selected power supply design **125**. These controls may allow for visualization of aspects of the selected power supply design **125**, including the relative contributions of component supplies to the total values of various key parameters.

The schematic diagram **815** may display the selected power supply design **125** with each power supply component **205** or functional block of the schematic indicated in a different color or other visual identification.

The user interface **110**-E may further include project charts **1005** determined by the architecture navigation module **436** that graphically represent the relative contribution of each feature block to the whole power supply design **125**. For example, the project charts **1005** may represent the relative contributions of each feature block according to key parameters, such as power dissipation, BOM cost, and footprint. Through use of the project charts **1005**, a user may determine the relative contributions of each power supply design **125** according to the key parameters.

The user may further determine whether one of the supplies in the power supply design **125** is making too large of a contribution and may take corrective action. For example, if one power supply component **205** is responsible for most of the footprint, the user may select another power supply component **205** with a smaller footprint, if one is available. For example, an alternate solutions tab of the solution information **1010** may allow the user to choose another power supply component **205**.

Upon selection of a create project details control **1015**, the power supply design **125** may be input into a circuit design tool for further analysis.

Export Capability

As explained above, once a circuit design has been established and a PCB layout created, the schematic content and PCB layout content can be exported by the design synthesis tool. The exported file then can be imported into a CAD tool of the user's choosing. Further, the user of the design tool can select CAD and PCB layout tool formats for the export. The schematic and PCB layout content is then converted by the design tool to the specified formats during the export process.

FIG. **11** illustrates an example of an implementation of a system **1100** that includes this export functionality. As shown, the system includes a processing resource **1102** coupled to a non-transitory storage device **1104**, an input device **1106**, and an output device **1108**. The processing resource **1102** may include a single processor or core, multiple processors or cores, a single computer, multiple computers, or any other type of processing resource. The non-transitory storage device **1104** includes volatile storage (e.g., random access memory), non-volatile storage (e.g., magnetic storage, optical storage, solid-state storage, etc.), or combinations thereof. The input device **1106** may include a keyboard and a mouse or other pointing device. The output device **1108** may include a display.

The non-transitory storage device **1104** includes various executable software modules **1110**-**1118**. Each module is executable by the processing resource **1102**. FIG. **12** illustrates an embodiment of the system **1100** including a user interface engine **1200**, a schematic generator engine **1204**, a PCB layout generator engine **1206**, a simulation engine **1208**, and an export engine **1210**. Each engine **1200**-**1210** is implemented as the processing resource **1102** executing the corresponding module **1110**-**1118**. Thus, the user interface engine **1200** is implemented as the processing resource **1102** executing the user interface module **1110**. The schematic content generator engine **1204** is implemented as the processing resource **1102** executing the schematic content generator engine **1112**. The PCB layout generator engine **1206** is implemented as the processing resource **1102** executing the PCB layout generator module **1114**. The export engine **1210** is implemented as the processing resource **1102** executing the export module **1118**.

The user interface module **1110** is the same or similar as the user interface module **402** described above regarding FIG. **4**.

The schematic content generator module **1112** may include one or more of the modules of FIG. **4** such as the requirements module **404**, the architecture determination module **406**, the component determination module **408**, the circuit design module **410**, the circuit optimization module **412**, and/or the schematic determination module **414**. An explanation of those modules (and thus the schematic content generator module **1112**) can be found above and is not repeated here. For each component included in the schematic, the design synthesis tool includes a graphical symbol for the component and may also include one or more parametric attributes. The attributes may include electrical values such as inductance, DC resistance, etc. In addition, the attributes may include the reference designator or name, the manufacturer and/or part number of the component. The attributes also may include a footprint for the component. The footprint specifies the copper landing area for the component's pins. For example, if the component has 16 pins, then the footprint will have 16 landing areas where the pins will contact a PCB. As further explained below, when the schematic content and PCB layout are exported, the component footprint data may be included in the exported data.

The PCB layout generator module **1114** may include the board layout module **416** described above with respect to FIG. **4**. An explanation of the board layout module thus is not repeated here. The PCB layout generator module **1114** preferably permits a user to vary or change various aspects of the PCB design. Such aspects include, for example, the thickness of the board, the number of conducting layers used, whether and where fans are included for cooling purposes, the amount of airflow that is used, the amount, location and size of conducting material (typically copper) that is used for heat sinking, etc. Such changes or added components may be included in the PCB layout and included with the export of the PCB layout.

Electrical and thermal simulations can be performed using the simulation module **1116** which may include the electrical simulation module **418** and the thermal simulation module

420 also described above with regard to FIG. 4. Based on the results of the simulations, the user may opt to alter the PCB layout in some way as noted above (e.g., changing the thickness of the board, changing the number of layers, adding a fan, changing the airflow, changing the position and size of the conducting material, etc.).

Once the circuit schematic and PCB layout designs are completed to the user's satisfaction, the user can cause the design synthesis tool to export either or both of the schematic content and the PCB layout content to a file to be subsequently imported into a CAD tool. This export function preferably is implemented by the export engine **1210** upon the user selecting the CAD File Export software control **1300** in a GUI as illustrated in FIG. **13**. This software control may be included in a GUI, such as the GUIs depicted in FIGS. **8**-**10**.

Once the user selects the CAD File Format software control **1300**, a GUI as in FIG. **14** may be displayed on the output device **1108**. The left-hand side of the GUI of FIG. **14** includes various choices for a format for the schematic content. The right-hand side of the GUI includes various choices for a format for the PCB layout. The example of FIG. **14** shows n formats for the circuit schematic content and y formats for the PCB layout. The descriptor for each selectable format may be the name of the format (e.g., Altium Designer). The number of selectable circuit schematic formats (n) may be the same as, or different from, the number of selectable PCB layouts (y). Further, the selectable choices of circuit schematic formats may be different from the selectable formats for the PCB layout, or one or more all of the choices of the circuit schematic formats may be the same as the choices of the PCB layout formats. The user uses the input device **1106** to select (e.g., click) the desired formats. In the example of FIG. **14**, the user has selected Format 2 for the circuit schematic export and Format a for the PCB layout export.

A selectable option **1402** is also provided by which a user can cause a footprint library to be included with the schematic export. A footprint is associated with each component in the schematic. As noted above, the footprint specifies the dimensions of the landing areas for the contact points (e.g., pins) of that component.

The user then selects the "EXPORT" button at the bottom of the GUI to begin the export process. The export engine **1210** then exports the schematic content and the PCB layout to one or more files commensurate with the selected formats. The export engine **1210** converts the schematic content and the PCB layout from their native format to the formats selected by the user.

The schematic conversion process involves taking the attributes of the original schematic design and converting them into a format that is understandable and may be read in by the receiving CAD tool. These schematic attributes may include one or more of the following: connecting wire start points, end points and vertices; component locations and attributes such as the manufacturer's part number and parametric specifications; component symbols; other schematic symbols such as ground and power inputs and loads; the netlist identification of wires and components; and other key elements for the schematic design that are required by the destination CAD tools. Since different CAD tools may require different attributes than others, the conversion process keeps track of the requirements for each CAD tool and extracts the necessary information for the appropriate CAD tool and puts it in a format that is able to be read by the CAD tool. This may be an ASCII text format or a binary format.

The PCB conversion process involves taking the attributes of the original design and converting them into a format that is understandable and may be read in by the receiving CAD tool. These PCB attributes may include one or more of the following: conducting layer stack up; conducting material size and location; via hole size, location and start/stop layers; conducting trace size and location; conducting metrical pour size and location; board size; the netlist identification of conducting layer elements; electrical and physical component (inductors, capacitors, resistors, diodes, integrated circuits, test points, etc.) attributes, footprints and location; and other elements for the PCB design that are required by the destination CAD tool. Since different CAD tools may require different attributes than others the conversion process keeps track of the requirements for each CAD tool and extracts the necessary information for the appropriate CAD tool and put it in a format that is able to be read by the CAD tool. This may be an ASCII text format or a binary format.

FIG. **15** illustrates an example of a method to generate a circuit schematic, PCB layout, and export the completed design to a CAD format of the user's choosing. The operations depicted in FIG. **15** may be performed in the order shown or in a different order. Further, the operations are performed by the various engines shown in FIG. **12**.

At **1502**, the method includes receiving user input (e.g., via the user interface engine **1200**). The received user input may include various input and output values for the circuit to be designed and other variables pertaining to the circuit. On the basis of the received user input, the method then generates the schematic content as explained previously (**1504**). Generating the schematic content may include such information as:

- coordinates for wires in a circuit schematic,
- locations for component symbols,
- information about each component represented by a component symbol, the information to include some or all of: the number and name of pins for the component, function of the pins, size and location of symbol elements used in the symbol, the component manufacturer, part number, electrical specifications, and marketing information, and
- component symbol pin mapping information to map pins depicted in the symbol to PCB footprint pins

A BOM and a PCB layout are generated at **1506** and **1508**, respectively. Generating the PCB layout may include such information as

- locations and shapes of conductive material on the PCB and information about which layer of the PCB such conductive material is to be located on,
- placement of vias on the PCB including diameter, surrounding copper area, and start and stop PCB layers,
- locations of components from the BOM on the PCB including whether each such component is to be on the top or bottom layer of the PCB,
- number of layers and the thickness of the conductive material of the PCB and
- PCB footprint information for each component in the BOM including copper landing areas for each such component, solder mask information, paste mask information, and mechanical information, dimensions of each such component.

At **1510**, the method includes performing a simulation on the PCB layout. The simulation may include, for example, a thermal simulation and/or an electrical simulation. At **1512**, a user may modify the PCB layout on the basis, for example, of the results of the simulation. The user may make such modifications via the user interface engine **1200**. The line between the simulation performance operation **1510** and the PCB layout modification operation **1512** is a double headed arrow to indicate that the method may iterate between modifying the PCB layout and performing a simulation on the modified layout.

At **1514**, the method includes receiving user input (e.g., via the user interface engine **1200**) as to whether to include PCB layout footprint data with the schematic export. If the user indicates his or her desire to include such data, then the footprint data is included with the PCB layout data.

The user then selects a desired CAD tool format at **1516** via, for example, the user interface engine **1200**. An example of how a user performs this operation is depicted in FIG. **14** and discussed above. At **1518**, the export engine **1210** then exports the schematic content and/or the PCB layout and, if specified in **1514**, the PCB footprint data to the specified CAD tool format. The exported file may be saved to non-volatile storage at a location chosen by the user. The user can then import (**1520**) the previously exported schematic and/or PCB layout data to the CAD tool desired by the user (presumably a CAD tool of a format selected by the user at **1516**).

Once imported into the CAD tool, the user can use the CAD tool to integrate the schematic and/or PCB layout into a larger design, generate net lists, run simulations, generate Gerber files, and perform other operations typical of CAD tools. The user advantageously did not have to manually enter the circuit design into the CAD tool due to the export functionality of the design synthesis tool described herein.

The above discussion is meant to be illustrative of the principles and various embodiments of the present invention. Numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

What is claimed is:

1. A method, comprising:
- receiving user input;
- generating schematic content for a circuit based on the received user input and a printed circuit board (PCB) layout based on the circuit, the generated schematic content including:
  - coordinates for wires in a circuit schematic,
  - locations for component symbols,
  - information about components represented by the component symbols, the information including, for each of the components, the number and name of pins for the respective component, function of the pins for the respective component, and size and location of symbol elements used in the component symbol for the respective component, and
  - component symbol pin mapping information to map pins depicted in the component symbols to PCB footprint pins; the method further comprising:
- generating a bill of material (BOM) for the circuit;
- receiving a user selection of a computer-aided design (CAD) tool format from a plurality of CAD tool formats and a PCB layout tool format from a plurality of PCB layout tool formats;
- receiving a user selection to include, with an export of the schematic content, footprints for the components used in the schematic content or components used in the PCB layout;
- modifying at least one of the schematic content and the PCB layout or adding components to at least one of the schematic content and the PCB layout before exporting; and
- exporting the schematic content, the PCB layout, and the PCB footprints to one or more files in accordance with the selected CAD tool format and the selected PCB layout tool format.

2. The method of claim **1** further including generating the PCB layout, wherein generating the PCB layout includes generating the PCB layout to include:
- locations and shapes of conductive material on the PCB and information about on which layer of the PCB the conductive material is to be located;
- placement of vias on the PCB including diameter, surrounding copper area, and start and stop PCB layers;
- locations of components from the BOM on the PCB including whether each of the components is to be on the top or bottom layer of the PCB;
- number of layers and the thickness of the conductive material of the PCB; and
  - PCB footprint information for each of the components in the BOM including, for each of the components in the BOM, copper landing areas, solder mask information, paste mask information, mechanical information, and dimensions.

3. The method of claim **1** further comprising importing the files into a CAD tool.

4. The method of claim **1** further comprising performing a simulation on at least one of the PCB layout and the schematic content before exporting.

5. A non-transitory storage device containing instructions that, when executed by a processing resource, cause the processing resource to:
- receive user input;
- generate schematic content for a circuit based on the received user input wherein the instructions cause the processing resource to generate the schematic content to include:
  - coordinates for wires in a circuit schematic,
  - locations for component symbols,
  - information about components represented by the component symbols, the information including, for each of the components, the number and name of pins for the respective component, function of the pins for the respective component, and size and location of symbol elements used in the component symbol for the respective component, and
  - component symbol pin mapping information to map pins depicted in the component symbols to PCB footprint pins; the instructions further causing the processing resource to:
- generate a bill of material (BOM) for the circuit;
- generate a printed circuit board (PCB) layout based on the circuit;
- receive a user selection of a computer-aided design (CAD) tool format from a plurality of CAD tool formats and a PCB layout tool format from a plurality of PCB layout tool formats;
- receive a user selection to include footprints for the PCB layout with an export of the schematic content;
- per user input, modify the PCB layout or add components to the PCB layout before export; and
- export the schematic content, BOM, PCB layout and PCB footprints to one or more files in accordance with the selected CAD and PCB layout tool formats.

6. The non-transitory storage device of claim **5** wherein the instructions cause the processing resource to generate the PCB layout to include:

locations and shapes of conductive material on the PCB and information about on which layer of the PCB the conductive material is to be located;

placement of vias on the PCB including diameter, surrounding copper area, and start and stop PCB layers;

locations of components from the BOM on the PCB including whether each of the components is to be on the top or bottom layer of the PCB;

number of layers and the thickness of the conductive material of the PCB; and

PCB footprint information for each of the components in the BOM including, for each of the components in the BOM, copper landing areas, solder mask information, paste mask information, mechanical information, and dimensions.

7. The non-transitory storage device of claim **5** wherein the instructions further cause the processing resource to perform a simulation on the PCB layout before export.

8. A system, comprising:

a user interface engine to receive user input via a graphical user input (GUI);

a schematic content generator engine to generate schematic content including a bill of material (BOM) for a circuit based on the received user input, wherein schematic content generator engine generates the schematic content to include:

coordinates for wires in a circuit schematic,

locations for component symbols,

information about components represented by the component symbols, the information including, for each of the components, the number and name of pins for the respective component, function of the pins for the respective component, and size and location of symbol elements used in the component symbol for the respective component, and

component symbol pin mapping information to map pins depicted in the component symbols to PCB footprint pins; the system further comprising:

a PCB layout generator engine to generate a PCB layout based on the generated schematic content,

wherein the user interface engine is configured to receive a user selection of a computer-aided design (CAD) tool format and a PCB layout tool format and to receive a user selection to include PCB footprints for components used in the circuit schematic with an export of the schematic content; the system further comprising:

an export engine to export the schematic content, BOM, PCB layout and PCB footprints to one or more files in accordance with the selected CAD and PCB layout tool formats; and

a simulation engine to perform a simulation on the schematic content before the export engine exports the schematic content and BOM.

9. The system of claim **8** wherein the PCB layout generator engine is configured to generate the PCB layout to include:

locations and shapes of conductive material on the PCB and information about on which layer of the PCB the conductive material is to be located;

placement of vias on the PCB including diameter, surrounding copper area, and start and stop PCB layers;

locations of components from the BOM on the PCB including whether each of the components is to be on the top or bottom layer of the PCB;

number of layers and the thickness of the conductive material of the PCB; and

PCB footprint information for each of the components in the BOM including, for each of the components in the BOM, copper landing areas, solder mask information, paste mask information, mechanical information, and dimensions.

10. The system of claim **8** wherein the simulation engine is configured to perform a simulation on the PCB layout before the export engine exports the schematic content, BOM, PCB layout and PCB footprints to the one or more files.

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